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1st Session } { No. 1014

PROJECT MERCURY: MAN-IN-SPACE PROGRAM OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

REPORT

OF THE

COMMITTEE ON

AERONAUTICAL AND SPACE SCIENCES

UNITED STATES SENATE

DECEMBER 1, 1959

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LETTER OF SUBMITTAL

DECEMBER 1, 1959.

Hon. LYNDON B. JOHNSON,
Chairman, Committee on Aeronautical and Space Sciences,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: The following is the staff study on Project Mercury, the man-in-space program of the National Aeronautics and Space Administration, prepared pursuant to your request. The report, compiled by Dr. Earl W. Lindveit and reviewed by the other members of the professional staff, is a compilation of unclassified information gathered from the hearings of the committee, supplemented by additional data collected from governmental agencies and independent sources.

No attempt has been made by the staff to editorialize or to present other than factual data.

It is hoped that the material contained herein will prove of value to the members of the committee and the Senate as a whole, both as a reference document and as basic information for the review of the future of this program as it develops.

The staff wishes to point out that this is a new subject, and rapid and significant changes can be expected in the future. The technical aspects outlined in this report reflect the status of planning as of the date of publication.

Respectfully yours,

KENNETH E. BELIEU,
Staff Director.

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PROJECT MERCURY: MAN-IN-SPACE PROGRAM OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

December 16, 1959—Ordered to be printed
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Mr. JOHNSON, from the Committee on Aeronautical and Space Sciences, submitted the following

REPORT

INTRODUCTION

The purpose of this staff study, made at the request of the chairman, is to serve members of the Committee on Aeronautical and Space Sciences as a source of basic information on Project Mercury, the man-in-space program of the National Aeronautics and Space Administration.

The study is largely derived from unclassified information released by the National Aeronautics and Space Administration and testimony concerning Project Mercury given during hearings before this committee. The program descriptions are based upon current program planning. Since this is a highly advanced research and development program, the project is obviously subject to changes that may result from future developments and accomplishments characteristic of such research activities. Certain information with respect to revised schedules, obtained on a classified basis by the committee during inspection trips, is necessarily omitted.

The appendixes to the study include information that may prove helpful on various aspects of space flight and exploration. Included are unofficial comments and observations relating to Russia's manned space flight activities and also a complete chronology of all satellites, lunar probes, and space probes up to the present.

The announced objectives of Project Mercury are to: (1) place a manned space capsule in orbital flight around the earth; (2) investigate man's performance capabilities and ability to survive in a true space environment; and (3) recover the capsule and the man safely. Advanced space flight and full utilization of space will require the inclusion of human intelligence and human operations. Project Mercury is, therefore, a first step in the ultimate achievement of interplanetary space flight and the Mercury capsule vehicle is a steppingstone to larger systems in the future for the performance of scientific, civil, and military missions.

The importance of Project Mercury to the security of the United States has been recognized by giving the program the same "highest national priority" status accorded to the ballistic missile programs.

In addition to the national security requirements for the development of our space capabilities, it is evident that exploitation of the potentialities of outer space would be of benefit to mankind in general. During hearings before this committee, for example, the Administrator of NASA, Dr. T. Keith Glennan, indicated that the value of advances to be made by space satellites in meteorology and worldwide communications would "be counted in the billions of dollars."

Dr. Glennan has indicated that before the United States has succeeded in putting the first man into space via Project Mercury, the cost will have exceeded $200 million. Because it is essential to assure safe recovery of both the man and the capsule, and because of the many unknown factors that still exist, NASA has consistently refused to commit itself to any fixed launching date for the first manned orbital flight. The information given to the committee, however, called for unmanned tests extending through 1960. The first manned orbital flight will necessarily follow successful completion of the testing process.

Meaningful appraisal of this Nation's man-in-space program must inevitably be done in context with similar efforts underway in the U.S.S.R. The psychological impact of a Soviet "first" in this area could have tremendous effect on world opinion and play an important role in the "cold war." A sober reminder of Russian progress in this area was included in a statement by Senator Lyndon B. Johnson on August 3, 1959:

> Even though our man-in-space program has been given the same high priority accorded the ballistic missile programs, we are told that the Russians have the capability to put a man in space first.
>
> While we must not sell ourselves short, it is clear that this is no time for complacency. We must continue to work harder and faster, for we must realize that the Soviets are not going to stop so that we can catch up with them.

It should be noted that since this statement by the chairman, Russian space accomplishments have included first hitting—and then orbiting—the moon, and photographing its far side.

The successful launching of the Mercury capsule, utilizing the Atlas booster, the largest booster presently available, would in some ways represent the maximum achievement in this regard that could be expected from existing boosters. Subsequent accomplishments in manned space flight, particularly the achievement of greater control and maneuverability, would be dependent upon the availability of larger boosters. Under present planning, the Saturn would provide the first such large booster. At this time, insufficient information is available to permit evaluation of whether the proposed transfer of the Development Operations Division of the Army Ballistic Missile Agency and of the Saturn project to the National Aeronautics and Space Administration will, in fact, result in a closer integration of space activities, including manned space flight.

PART I. PROJECT MERCURY BACKGROUND

1. SUMMARY OF PROJECT MERCURY PROGRAM

The highest priority program now being conducted by the National Aeronautics and Space Administration is Project Mercury, the manned satellite program. The objectives of Project Mercury are to (1) place a manned space capsule in orbital flight around the earth, (2) investigate man's performance capabilities and ability to survive in a true space environment, and (3) recover the capsule and the man safely. Project Mercury is a national effort of the United States, conceived and organized to send man on his first short step into space. The NASA Space Task Group located at the Langley Research Center, Hampton, Va., is administering Project Mercury.

The McDonnell Aircraft Co. of St. Louis, Mo., was selected to develop and manufacture the Mercury manned satellite capsule, which is bell-shaped like a round television tube about 6½ feet at the base and about 9 feet tall. The capsule will be wingless, have an extremely blunt leading face covered with a heat shield, and have high aerodynamic drag; it will be subject to various combinations of acceleration, heat loads and aerodynamic forces during boost and atmosphere-reentry phases. It is planned that an Atlas intercontinental ballistic missile rocket booster would launch the manned capsule in a circular orbit around the earth, at an altitude of between 100 to 150 miles. Upon completion of three orbits around the earth, descent from orbit would take place by use of retrothrust rockets in the capsule system. After being slowed down by aerodynamic drag, parachutes in the capsule system would billow out and further reduce descent speed, and recovery of the capsule could be made on land or water.

The Mercury capsule would be guided into the desired orbit through ground-based and booster equipment after which ground and capsule devices would determine the orbital path in flight. Each orbit of the capsule around the earth would take about 90 minutes. Inside the Mercury capsule the astronaut, wearing a pressurized flight suit, would be supported on a couch tailored to the exact contours of his body which would enable him to withstand the forces of acceleration on take-off and reentry. Food and water would be available to the astronaut during orbital flight, and the capsule would be subject to controlled pressure, temperature, and atmosphere composition.

The astronaut would have contact through voice communication with ground stations during flight. Capsule instrumentation would include two-way radios, receivers for command from the ground, telemetry equipment for transmission of data from the capsule to ground stations, and radio tracking beacons. Information on the astronaut's physical condition would be telemetered to ground stations. Other equipment would evaluate the astronaut's reaction to space flight, measure and monitor the internal and external capsule environment, and make scientific observations.

The astronaut would have the option of using manual or automatic control of the capsule during orbital flight. A control system of capsule attitude sensors, electronic stabilization devices, and reaction controls would be incorporated in the capsule. The reaction control would maintain the capsule in a specified orbital attitude and establish the proper angle for firing of the retrothrust rockets for reentry into the atmosphere, or for an unplanned termination of the mission. During manual control of the capsule the astronaut would be able to see portions of the earth and sky which would enable him to position the capsule to the desired orbital attitude.

Upon a signal initiated by either the astronaut, an automatic device within the capsule, or by a command link from ground control, the Mercury capsule's retrothrust rocket system would supply sufficient impulse for reentry into the atmosphere in less than one-quarter of an orbital revolution. This control over the capsule's point of reentry into the atmosphere would enable the landing area to be largely predetermined. After the capsule has landed recovery aids would include tracking beacons, smoke bombs, dye markers and other devices.

Among the Project Mercury safety control features are an emergency system enabling the astronaut to escape if anything goes wrong during launching, an escape-system separation of the capsule from the booster in an emergency situation before orbital altitude is reached, and after the capsule is in orbit the ability of the astronaut to reenter the atmosphere at any time by activating the retrorockets. Project Mercury includes ground testing, development and qualification flight testing, and astronaut training—orbital flight of the manned space capsule would be dependent upon a logical buildup of vehicle capabilities and scientific data.

2. PROJECT MERCURY HISTORY

The National Advisory Committee for Aeronautics, predecessor organization to the National Aeronautics and Space Administration, had a long history of research on problems of manned flight at ever-increasing speeds and altitudes. During the years 1956 and 1957 research experience in the fields of ballistic missiles and hypersonic flight led NACA to study the possibilities of utilizing ballistic missile boosters to provide the necessary velocities and altitudes for manned orbital and space flight. Such studies were intensified by NACA and the military services during 1957 and 1958.

At the NACA Langley Aeronautical Laboratory a working committee studied various manned satellite plans and in March 1958 concluded that ballistic-entry vehicles launched with existing ICBM (intercontinental ballistic missile) propulsion systems should be utilized in launching the first manned satellite. The details of a vehicle were drafted, and by June 1958 a working group of representatives from the NACA Langley Aeronautical Laboratory and the NACA Lewis Flight Propulsion Laboratory was formed for the purpose of outlining a manned satellite program. The primary responsibility for research and development leading to manned space flight was assigned to NACA 2 months later.

A Joint Manned-Satellite Panel was established in September by NACA and the Advanced Research Projects Agency of the Department of Defense. It utilized studies made by NACA Langley and Lewis Laboratories, as well as the advice and assistance of the military services, and formulated specific plans for a program of research leading to manned space flight. The plans were approved in early October by the Director of ARPA and the Administrator of the National Aeronautics and Space Administration, which superseded the NACA as of October 1, 1958. Upon approval of plans by the Administrator of NASA a Space Task Group composed of personnel from Langley and Lewis began operations on Project Mercury at the NASA Langley Research Center.

Research and development program

Significant research and development testing of both model and full-scale configurations for the man-in-space project had taken place at the NACA Langley Laboratory during 1958. Prior to the actual establishment of NASA and the Space Task Group this research and development program had included: (1) aerodynamic data for the capsule; (2) aerodynamic data for the solid-fuel booster; (3) model and full-scale water-impact tests of the capsule and parachute system; and (4) design, construction, and centrifuge proof tests of a formed-couch pilot support system. Joint studies on the structural design, control systems, and overall system integration were performed by personnel of the NACA Langley Laboratory and the NACA Lewis Flight Propulsion Laboratory.

Capsule

On the basis of NACA studies and discussions with the Department of the Air Force which had been conducting related studies, the new NASA Space Task Group prepared preliminary specifications for the proposed Mercury space capsule for distribution to industrial firms by the end of October 1958. A contractors' briefing attended by some 40 potential bidders on the capsule was held at the Langley Research Center on November 7. More detailed specifications were then prepared and distributed to about 20 manufacturers who had stated an intention to bid on the project. Twelve proposals for construction of the capsule were received by NASA in December and on January 9, 1959, final negotiations were begun with the McDonnell Aircraft Corp., with which a contract was signed on February 6, 1959, to design, develop, and build the capsule. Delivery of the first unmanned qualification test capsule was scheduled for December 1959.

Booster vehicles

The two types of boosters required for the man-in-space project were: (1) large liquid fuel ballistic missile boosters for orbital flights and for hardware qualification flights, and (2) smaller solid fuel boosters for research and development flights.

In the process of negotiating for the booster vehicles NASA Space Task Group personnel visited the Air Force Ballistic Missile Division, the Army Ballistic Missile Agency, and the Air Force Missile Test Center. Arrangements were made for ordering the required ballistic missile boosters from the military services, including Redstone and Jupiter boosters to be used in the flight test program and Atlas boosters to be used both in flight tests and in orbital flights. (NASA has since withdrawn the Jupiter from the Mercury program.)

A test propulsion vehicle comprising a cluster of four large solid propellant rocket motors was designed by the Langley Research Center staff and contracts were let to North American Aviation, Inc., for the solid fuel motors and the detailed design and construction of the airframes.

Astronaut selection

During the period since early November 1958 aeromedical personnel have been assigned to the NASA Space Task Group by the Army, Navy, and Air Force to work in conjunction with personnel from the Space Task Group, from NASA headquarters, and from the NASA Special Committee on Life Sciences. The group established an astronaut selection procedure, set up qualifications and requirements, and selected a group of 110 potential astronauts. In the process of final selection, seven astronauts were chosen and entered a training program at the Langley Space Task Group in early April 1959.

3. NASA ORGANIZATION FOR PROJECT MERCURY

The prime responsibility for Project Mercury is exercised by the Administrator of NASA, with the advice and assistance of ARPA through the Joint NASA-ARPA Manned-Satellite Panel. Advice on all considerations regarding the human pilot in Project Mercury is provided by the NASA Special Committee on Life Sciences which includes members from the Departments of Army, Navy, and Air Force, the Atomic Energy Commission, and private life. The technical direction of Project Mercury is the responsibility of the NASA Space Task Group which includes as working members technical and medical personnel from the Army, Navy, and Air Force.

The Space Task Group is a unit of the National Aeronautics and Space Administration located at NASA's Langley Research Center, Hampton, Va. The group came into existence in the fall of 1958 with specific responsibility for putting a manned satellite into orbit with subsequent safe recovery. During the year preceding formation of the task group, several members of the Langley staff had conducted experimental and theoretical studies into problems of manned space flight. Dr. T. Keith Glennan, NASA Administrator, ordered that the task group be organized, and the Langley Center released a number of scientists to the group who formed its nucleus.

The Space Task Group reports directly to NASA's Office of Space Flight Development in Washington. Activities of the Operations Division of the Group include launching, recovery, ground support, and developmental testing. The Flight Systems Division conducts work on a parallel with systems application, and its responsibility involves heat shielding, structures, navigation, rocket boosters, escape, life support and systems integration. The work within the Engineering and Contract Administration Division is design engineering, specifications, contract negotiation and contract monitoring. Liaison is maintained with the Defense Department, through the Advanced Research Projects Agency, and with the NASA Life Sciences Committee. Aeromedical personnel assigned to the Space Task Group (predominantly from the Air Force) maintain direct technical and working liaison with aeromedical laboratories of the various military services. Available to the Space Task Group are human factors consultants experienced in the selection and training of crew members for such special military missions as high altitude balloon and research aircraft flights, and nuclear-propelled submarine exploratory and test cruises.

The Space Task Group calls on facilities of NASA, the armed services, universities and industry in the Project Mercury program. Human factors facilities in such fields as weightlessness and high acceleration and deceleration are being furnished by the Department of Defense.

4. RELATIONSHIP OF X–15 RESEARCH AIRPLANE TO MANNED SPACE FLIGHT

The X–15 rocket-powered research airplane is the most advanced research airplane in the history of aeronautics. It is anticipated that sometime within the next 2 years it will carry its pilot out beyond the earth's effective atmosphere at speeds never before approached by a piloted aircraft.

The X–15 project is sponsored jointly by the U.S. Air Force, the National Aeronautics and Space Administration, and the U.S. Navy. In 1952, foreseeing the necessity of space flight research, the National Advisory Committee for Aeronautics inaugurated studies of the problems which would have to be solved before manned space flight could be feasible. Two years later after these problem areas had gone through aerodynamic studies including wind tunnel tests, NACA established preliminary specifications for an airplane best suited as a research vehicle for studies of aerodynamic heating, stability and control, and pilot reaction at hypersonic speeds and at altitudes up to 100 miles. The result, the X–15, was built by North American Aviation, Inc., and powered by the XLR–99, an advanced airplane rocket engine manufactured by Reaction Motors Division of Thiokol Chemical Corp.

Of the three X–15 airplanes to be built, two have already been delivered to Edwards Air Force Base, Calif., adjacent to NASA's Flight Research Center, where contractor demonstration flights are now underway. Pending delivery of the XLR–99 engines, the early powered flights of the X–15 make use of a combination of two rocket motors totaling 16,000 pounds of thrust. The XLR–99 will be capable of producing more than 50,000 pounds of thrust and speeds over 3,000 miles per hour.

After the contractor demonstration flights, the X–15 will be turned over to the Government for a NASA-conducted research flight test program. This phase of the program is also a cooperative effort and the X–15 test pilot pool will consist of specially trained NASA, Air Force, and Navy aviators. The Air Force will assist in funding the research flight program. Following a carefully prearranged flight plan, the plane's performance will be gradually increased until it reaches maximum capability. Tracking and telemetry recording equipment has been installed under the supervision of the NASA from Wendover Air Force Base, Utah, to Edwards, along the 485-mile route over which the X–15 will fly. The plane will be heavily instrumented so that engineers and technicians on the ground will be able to monitor the effects of high altitudes and speeds on the aircraft's structure and performance. In addition, special instrumentation will record the pilot's physiological reactions. The X–15 is not equipped with conventional takeoff and landing gear. It is carried to 38,000 feet by a modified B–52, dropped, and then it continues in flight under its own rocket power. The plane lands on skids.

The rocket powerplant, fueled with liquid oxygen and liquid ammonia, has a maximum burning time a little under 4 minutes. In a flight to the edge of space and back, which will take less than 30 minutes, the major portion will be unpowered or gliding flight, similar to a ballistic trajectory. The pilot will fly a programed flight path. Angle and rate of climb during powered flight will determine the trajectory. After engine burnout, the plane is committed to its course. Above an altitude of about 30 miles the X–15's control surfaces will no longer be effective. However, the pilot can maintain proper ballistic attitude by activating small control rockets in the nose and wings. Aircraft attitude is extremely important during the flight, especially while the plane is reentering the atmosphere, and aerodynamic heating can become critical. Once in the atmosphere, the pilot will glide-land the plane using conventional controls.

Each flight of the X–15 during the research program will provide scientific information applicable both to aerodynamics and space flight. Some of the areas for which the X–15 will provide research information are:

Aerodynamic heating: It is anticipated that the aircraft will encounter temperatures up to 1,200° F. How will this affect the Inconel X airframe; how much and at what rate will heat transfer from one section of the plane to another?

Aircraft control and stability: How will an aircraft perform and how will it handle under accelerations and decelerations up to the order of 7 G's?

Exit and reentry data: This research information will figure importantly in all future manned space vehicles which must guarantee safe passage both in and out of the earth's heavy blanket of atmosphere.

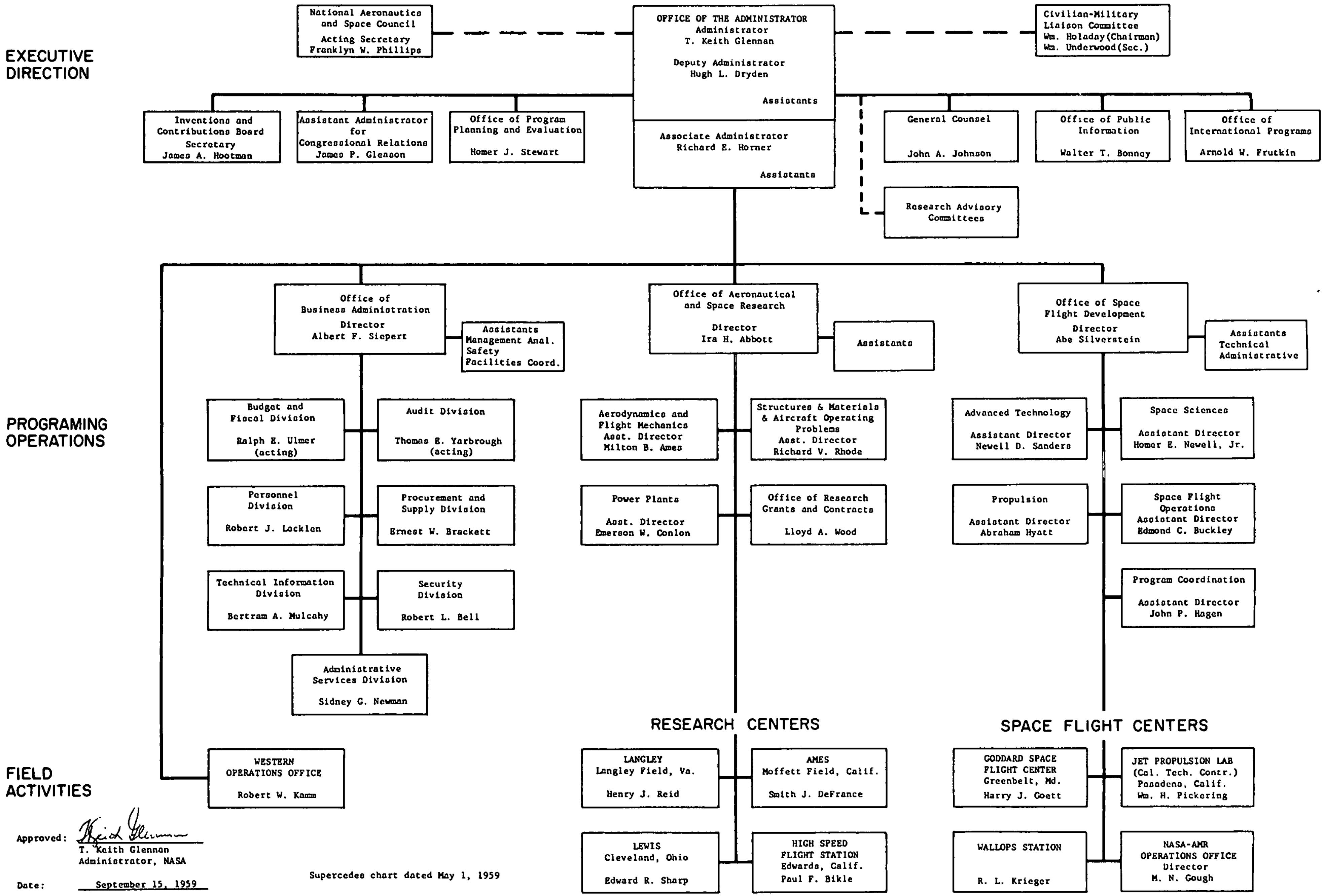
Physiological and psychological human reaction: The X–15 pilot will be subjected to the longest period of weightlessness yet encountered, something on the order of 5 minutes. The force on his body during the reentry maneuver will be about seven times his own weight. At hypersonic speeds and at extremely high altitudes, pilot reaction must be swift and sure.

Research information resulting from the X–15 program will be made available to industry and to the military services both in a series of major conferences and by means of technical reports. Much of the experience and results to be gained from the X–15 flights may be important to the successful execution of Project Mercury and possible subsequent projects.

On November 3, 1959, an explosion and fire took place in the X–15 shortly after it was dropped from the B–52 mother ship at an altitude of about 40,000 feet for a powered test flight. The explosion took place shortly after the engines were ignited and the pilot jettisoned the fuel supply and made an emergency landing. The pilot was uninjured but considerable damage was done to the X–15's fuselage and front landing gear. The full extent of the damage, and its effect on the overall X–15 program, has not yet been determined.

The currently planned follow-on to the X–15 is the Dyna-soar, a hypersonic rocket-boosted vehicle with sweptback delta wings capable of glide speeds in excess of 12,000 feet per second. The purpose of the manned Dyna-soar glider is to provide research information more advanced than that obtainable from the X–15 and to indicate whether such a vehicle has military possibilities. Overall

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



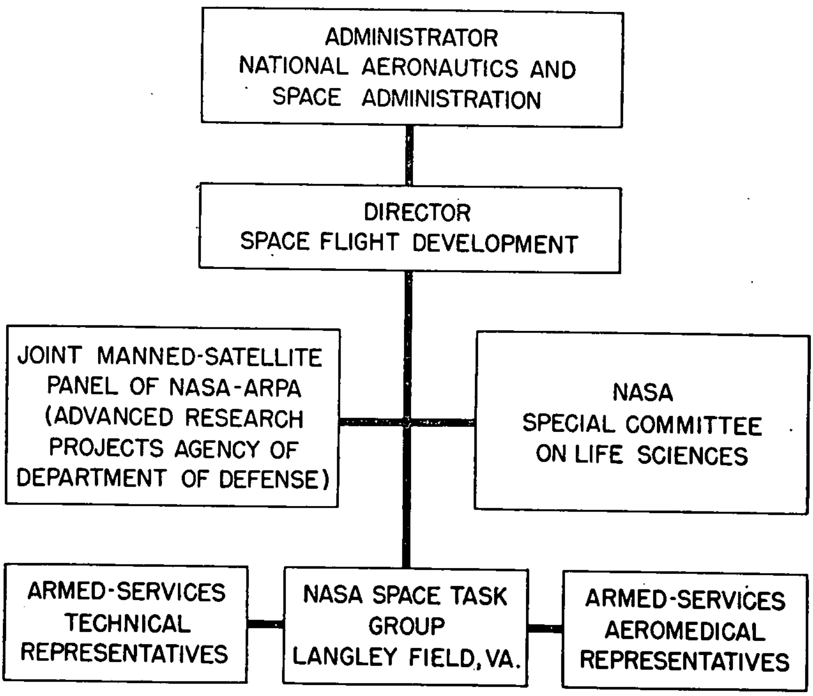
Approved: T. Keith Glennan
Administrator, NASA

Date: September 15, 1959

Supercedes chart dated May 1, 1959

technical control of the project is the responsibility of the Air Force, acting with the advice and assistance of NASA, which is also responsible for the research instrumentations. On November 9, 1959, it was announced that the Air Force Wright Air Development Division would retain actual management of the program, that the Martin Co. would supply the booster phase of the project, and that the Boeing Airplane Co. would be responsible for the manned glider portion of the vehicle, including integration of the entire system and the development testing program. The Air Force stated that the first step in the development program would be the design and test of a glider which would bring a man back to a normal landing from hypersonic flight speeds, and also that unmanned and later manned gliders would be launched from Cape Canaveral down the Atlantic Missile Range to explore technical and military problems associated with flight at near-orbital speeds.

ORGANIZATIONAL STRUCTURE FOR MANAGEMENT AND DIRECTION OF PROJECT MERCURY



NOTE.—Recently the Space Task Group has become part of the NASA-Goddard Space Flight Center and reports through the Director of Goddard to the Director of Space Flight Development.)

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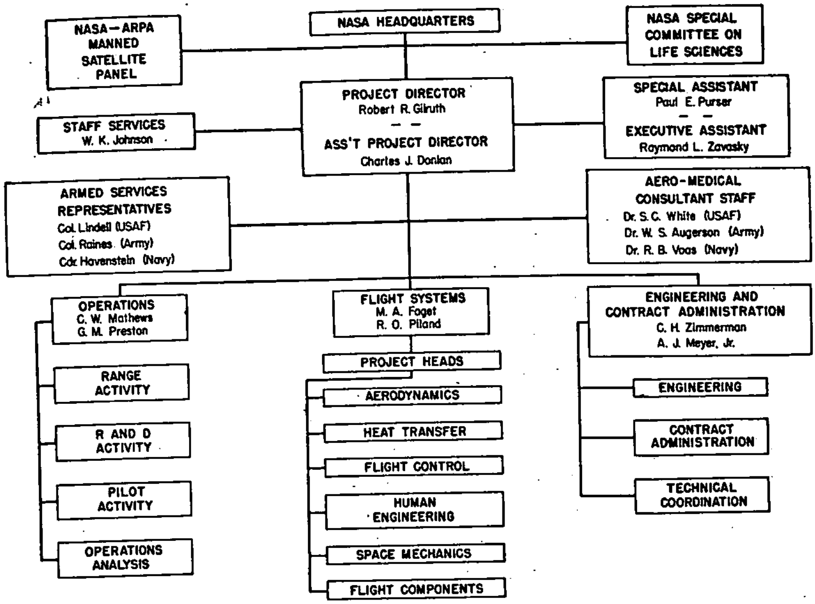
LANGLEY SPACE TASK GROUP ORGANIZATION



(NOTE.—The following staff additions and changes have been made in the Space Task Group organization. Walter C. Williams has been appointed Associate Director for Operations of Project Mercury; C. C. Kraft, Jr., and C. C. Critzos have been added to the staff of the Operations Division; and J. A. Chamberlin has replaced C. H. Zimmerman in the Engineering and Contract Administration Division. Charles J. Donlan is Associate Director for Development.)

5. PROPOSED ARRANGEMENT AND OPERATION OF THE MERCURY SYSTEM

Flight plan

1. According to present plan, an Atlas intercontinental ballistic missile booster would launch the manned capsule into orbit.
2. A nearly circular orbit would be established at an altitude between 100 to 150 statute miles to permit as much as a 24-hour satellite lifetime.
3. Descent from orbit would be initiated by the application of retrothrust rockets incorporated in the capsule system.
4. Parachutes, incorporated in the capsule system, would be used after the vehicle has been slowed down by aerodynamic drag.
5. Recovery on either land or water would be possible.

Description of proposed manned capsule system

1. *Vehicle.*—The manned capsule would have high aerodynamic drag, and would be statically stable over the range corresponding to flight within the atmosphere. The capsule would be designed to withstand any known combination of acceleration, heat loads, and aerodynamic forces that might occur during boost or reentry, with an extremely blunt leading face covered with a heat shield.

2. *Life support system.*—A couch, fitted into the capsule, would support the pilot during the orbital flight. Pressure, temperature, and composition of the atmosphere in the capsule would be main-

tained within allowable limits for human environment. Food and water also would be provided.

3. *Attitude control system.*—A closed loop control system, consisting of an attitude sensor with reaction controls, would be incorporated in the capsule. The reaction controls would maintain the vehicle in a specified orbital attitude, and would establish the proper angle for retrofiring or reverse firing of rockets, atmosphere reentry, or an abort or early termination maneuver. The pilot would have the option of manual or automatic control during orbital flight. During manual control the pilot would see portions of the earth and sky which would enable him to position the capsule to the desired orbital attitude.

4. *Retrograde system.*—A system would be provided to supply sufficient impulse to permit atmospheric reentry in less than one-fourth an orbital revolution after application of the retrorockets. These rockets would be fired upon a signal either initiated by a command link from ground control or by the man himself. The landing area could be predetermined because of this control over the capsule's point of reentry into the atmosphere.

5. *Recovery system.*—As the capsule reenters the earth's atmosphere and slows to a speed approximately that of sound, a drogue parachute would open to stabilize the vehicle. At this time narrow metal strips will be released to pinpoint the capsule's location by radar. When the altitude of the capsule decreases to a predetermined value, a landing parachute opens. The parachute will open at an altitude high enough to permit a safe landing on land or water. (The capsule will be buoyant and stable in water.) After landing, recovery aids will include: tracking beacons, a high-intensity flashing light system, a two-way voice radio, sofar bombs (a sound fixing and ranging system using an explosive element), and dye markers.

6. *Escape systems.*—In an emergency situation before orbital altitude is reached, escape systems would separate the capsule from the booster. After the capsule is in orbit, the space pilot could reenter the atmosphere at any time by activating the retrorockets. Other safety control features would also be incorporated in the capsule system.

Guidance and tracking

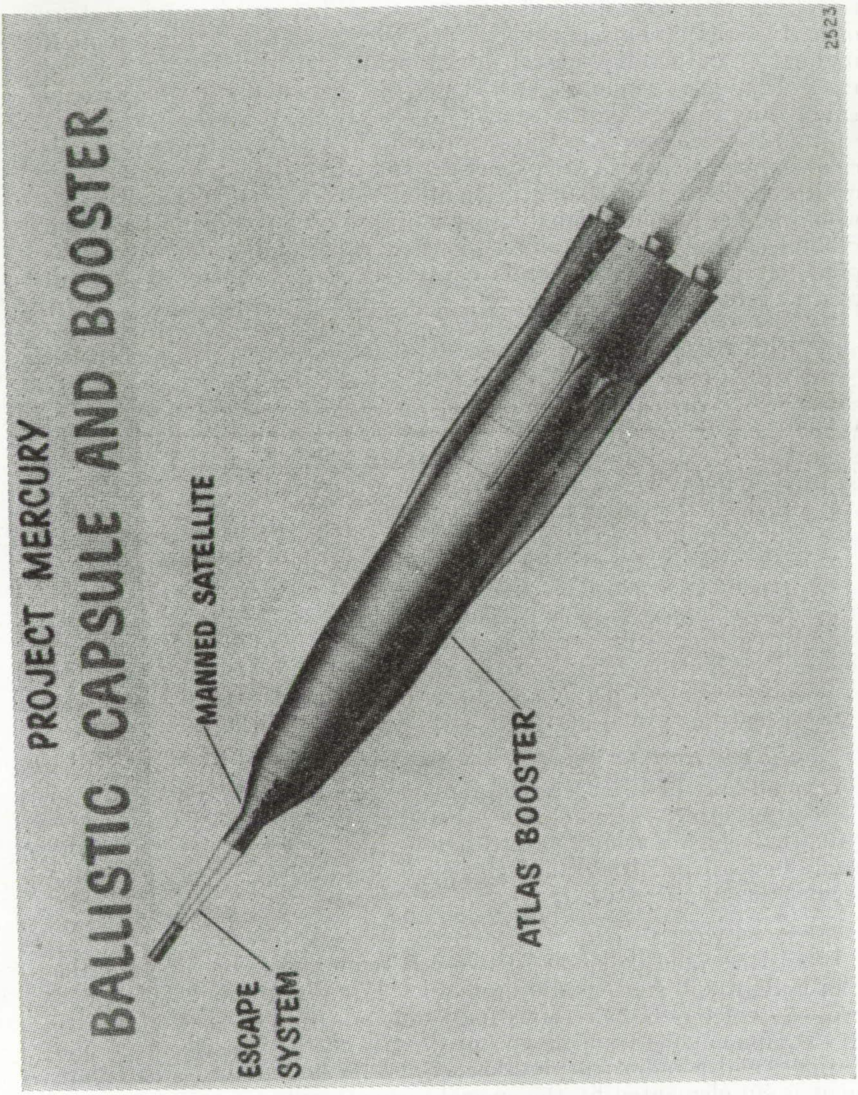
Ground-based and booster equipment would guide the capsule into the desired orbit. Ground and capsule equipment would then determine the vehicle's orbital path throughout its flight. The equipment would be used to initiate the vehicle's descent at the proper time and predict the landing area.

Communications

Provision would be made for two-way communication between the pilot and ground stations during flight. Equipment would include a two-way voice radio, a receiver for commands from the ground, telemetry equipment for transmission of data from the capsule to ground stations, and a radio tracking beacon. This communications equipment is supplemented by the special recovery aids.

Instrumentation

Biomedical instrumentation would sense, record, and telemeter data on the pilot's vital physiological functions during space flight.


PROJECT MERCURY
BALLISTIC CAPSULE AND BOOSTER
ESCAPE SYSTEM
MANNED SATELLITE
ATLAS BOOSTER
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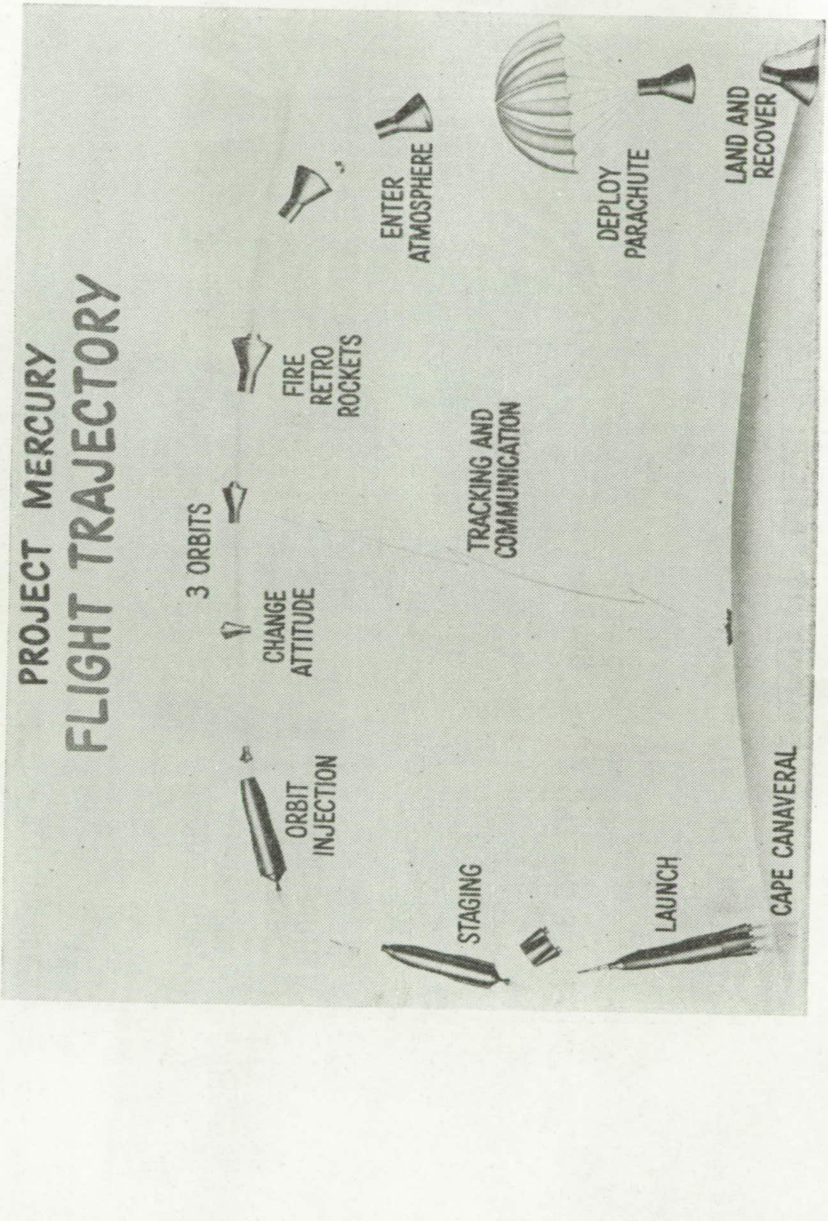
PROJECT MERCURY
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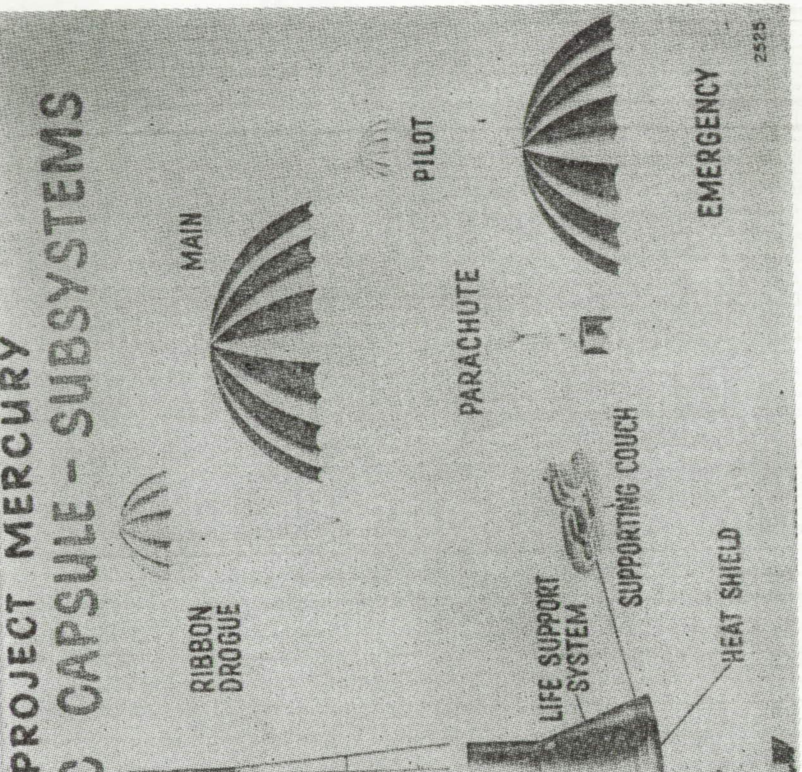
DEPLOY PARACHUTE
LAND AND RECOVER


PROJECT MERCURY
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PARACHUTE
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ESCAPE SYSTEM
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LIFE SUPPORT SYSTEM
SUPPORTING COUCH
HEAT SHIELD
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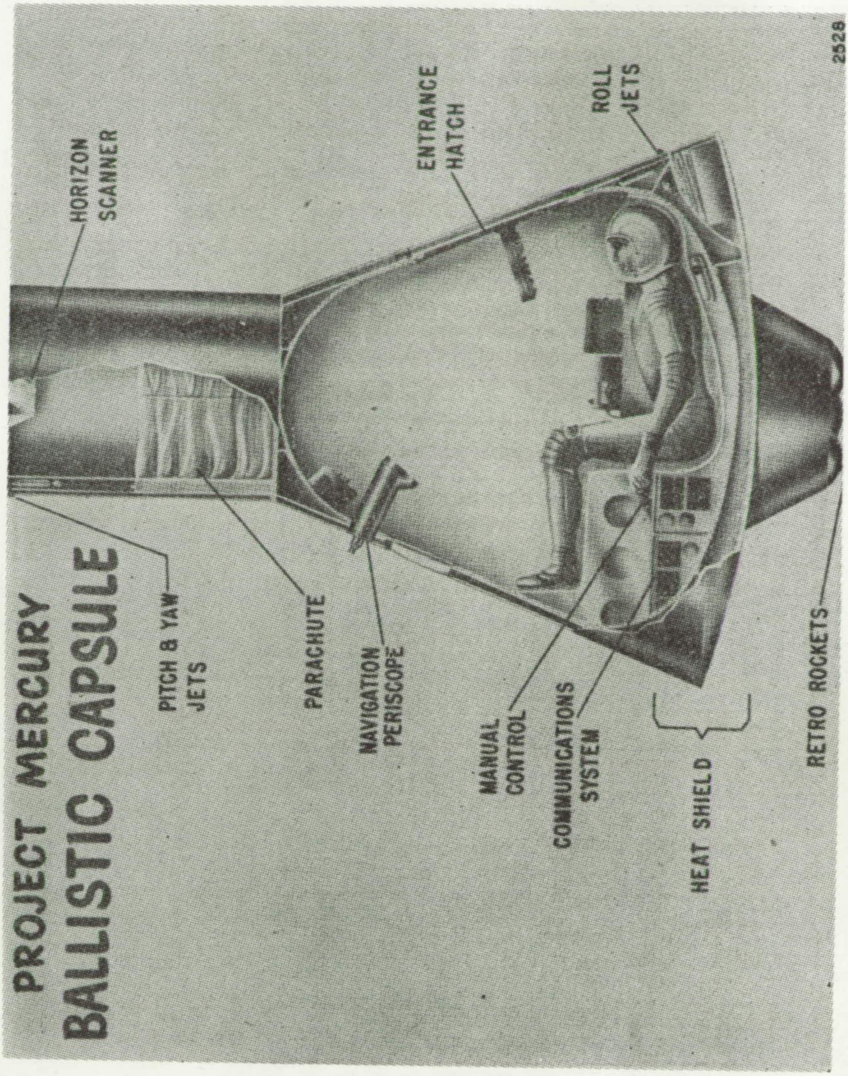
PROJECT MERCURY
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PITCH & YAW JETS
PARACHUTE
NAVIGATION PERISCOPE
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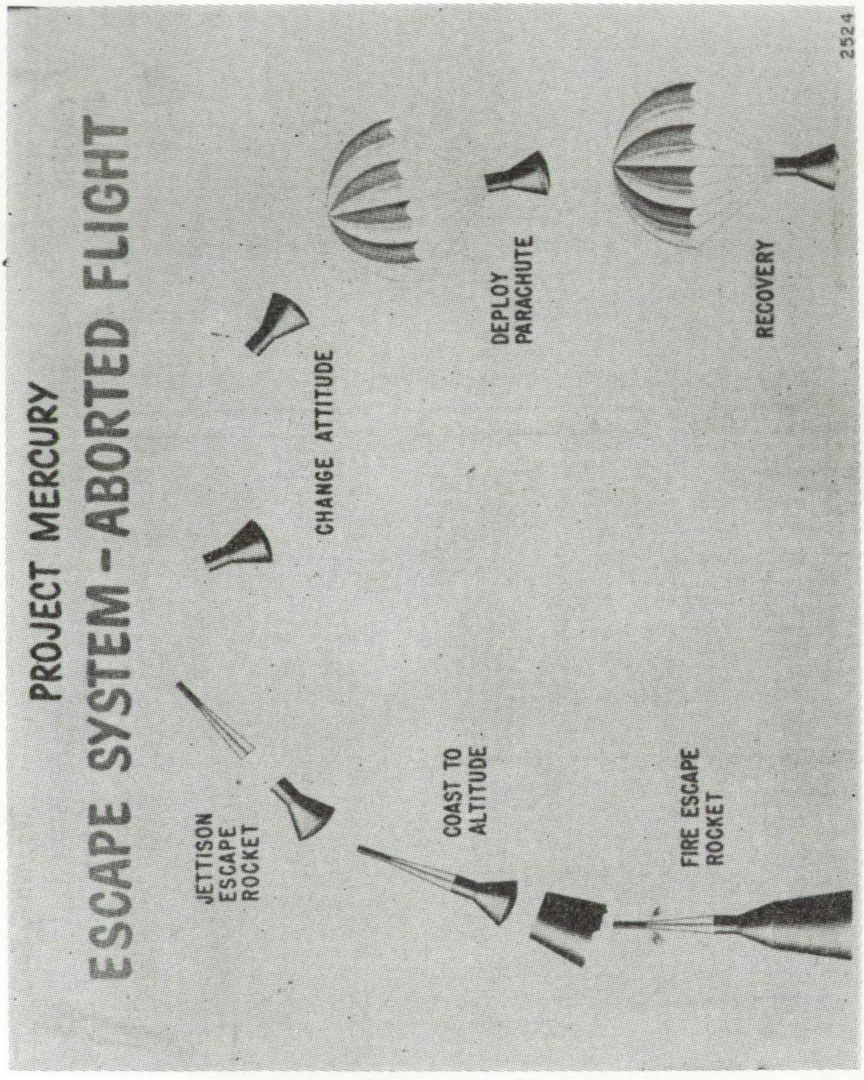

PROJECT MERCURY
ESCAPE SYSTEM - ABORTED FLIGHT
JETTISON ESCAPE ROCKET
CHANGE ATTITUDE
DEPLOY PARACHUTE
COAST TO ALTITUDE
FIRE ESCAPE ROCKET
RECOVERY
2524

6. VALUE AND COST OF THE MERCURY PROGRAM

On February 20, 1959, Dr. Hugh L. Dryden, Deputy Administrator of NASA, made the following statement before this committee concerning the value of the Project Mercury program:

> I think I mentioned that the situation is a little bit like determining the value of the airplane at the time of the Wright brothers. We have the utmost confidence, based on the past, if nothing more, that man is going to be in space, find useful things to do in space; that we must begin to study the problems associated with that.
>
> This project, in my mind, will advance the general technology of space at a faster rate than almost anything else that I can think of.
>
> If you do not have such an integrating project, what you get engaged in is a lot of research in various directions but not concentrated on accomplishing a mission. * * *
>
> Now, basic research is necessary, but this must be followed by research directed toward a mission to work out the applied research and the development problems, and this, I think, is one of the great returns which will come.
>
> A secondary result of all of this work already reflected rather widely throughout our industrial structure are the developments in materials, devices, fabricating methods which come because this is at the forefront of our technology.

In testifying before this committee on February 19, 1959, the costs of Project Mercury were identified by Dr. Glennan as follows:

> Project Mercury is budgeted at $37,661,200 in fiscal 1959; we are asking for $20,750,000 in supplemental funds before you now.
>
> The 1960 cost of Project Mercury is $70 million, and before we have completed this first U.S. effort to put man into space, the bill will have exceeded $200 million.

Although there were very extensive revisions in the programs to be funded by NASA's "Research and development" appropriation in the ensuing months, no changes were made in the estimates presented to the Congress for Project Mercury. It is now apparent, however, that the costs of Project Mercury will be greater than originally estimated—particularly if NASA construction and equipment funds are taken into account.

On the basis of present programing, the direct investment in Project Mercury during fiscal years 1959 and 1960 exceeds $152 million. This is approximately $24 million more than the amounts previously identified to the Congress by NASA as programed for Project Mercury. Approximately $16.4 million of this increase represents inclusion in the total of construction and equipment funds devoted specifically to the Mercury tracking network, while the remaining $7.4 million represents funds shifted from other NASA research and development programs to Project Mercury.

Recently, NASA adjusted its funding for Project Mercury by transferring $15 million from the "Research and development" appropriation to the "Construction and equipment" appropriation in order to expand the Mercury tracking network. These adjustments have been described in a letter of October 8, 1959, and a memorandum of October 22, 1959, from the Assistant Administrator for Congressional Relations of NASA to the committee chairman.

The pertinent extracts from the letter of October 8 and the memorandum of October 22 are as follows:

* * * * * * *

> Manned space flight is the NASA's top priority program. Increased costs have resulted from program complexities not foreseeable at the time the fiscal year 1960 budget was drawn up. The program, as justified, contained funds for work on the extension of man's space flight capability beyond Project Mercury; in order to make these funds available to Mercury, all such advanced work has been delayed

for a year and the 18-orbit mission has been reduced to a 3-orbit mission. An additional $7.515 million has had to be programed to maintain the Mercury rate of progress. Information will shortly be presented to Congress concerning a transfer of $15 million from the research and development appropriation to the construction and equipment appropriation for purchase of major equipment for the Mercury tracking range. However, this fund transfer does not represent a change in the revised total Mercury program.

* * * * * * *

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, D.C., October 22, 1959.

Memorandum to: Hon. Lyndon B. Johnson.
From: Assistant Administrator for Congressional Relations.
Subject: Transfer of funds between NASA appropriations to provide additional funds for the construction of the tracking network for Project Mercury.

1. It is the purpose of this memorandum to advise you of recent adjustments made in the fiscal year 1960 funds available to the National Aeronautics and Space Administration to provide additional funds for the construction of the tracking network for Project Mercury.

2. A total of $16,420,000 has been appropriated to date for construction and equipment of the Mercury network. The original estimates for the network were, of necessity, based on a minimum of detailed study. Detailed engineering studies now indicate an immediate need for an additional $15.0 million for the fiscal year 1960. A brief summary of the technical considerations which underlie the need for the additional funding follows:

(*a*) Additional facilities are required to further assure the safety of the Mercury pilot. For example, more extensive telemetry and data display equipment will be added at 15 locations to provide almost continuous contact with the pilot's physiological condition to physicians who will be located at the ground stations.

(*b*) Detailed study of possible equipment malfunctions, or abort conditions, has shown that additional radar tracking and telemetry reception will be essential in several areas to insure the safety of the pilot. Additional transportable tracking radars will be installed on Bermuda and on the West Coast of Africa to track the capsule in the event an abort becomes necessary during the launch phase. In this event, the capsule would not go into orbit and would have to be recovered between Bermuda and the African Coast.

(*c*) An additional transportable tracking radar will be added on the west coast of Australia to fix more precisely the exact position of the capsule on the "down under" portion of the orbit. This information is now considered essential for determining the timing of the retrorocket and the capsule recovery point.

(*d*) It is possible that, instead of completing three complete orbits before recovery, it might become necessary to bring the capsule in after only one orbit. An additional transportable tracking radar must, therefore, be located in West Central America to track the capsule during reentry after one orbit.

Pursuant to the authority contained in the general provisions of Public Law 86–213, the additional $15.0 million required in the NASA's fiscal year 1960 construction and equipment appropriation are being made available by the transfer of a like amount from the fiscal year 1960 research and development appropriation. Bureau of the Budget authorization for the transfer has been obtained in the form of approved apportionment revisions dated October 21, 1959.

* * * * * * *

After transfer of $15 million from the "Research and development" appropriation to the "Construction and equipment" appropriation, the current funding of Project Mercury is as follows:

	Fiscal year 1959	Fiscal year 1960 [1]	Total
Research and development	[2] $46,416,333	$74,362,000	$120,778,333
Construction and equipment	7,020,000	24,400,000	31,420,000
Total	53,436,333	98,762,000	152,198,333

[1] Includes fiscal year 1959 supplemental.
[2] Includes $8 million in ARPA transfer account.

A detailed description of the objectives, justification and program phases of Project Mercury is contained in the following passage taken from the printed record of hearings held by this committee on NASA's authorization request for fiscal year 1960.

Space Operations Technology—Manned Space Flight

1. OBJECTIVES

To provide a capability for accomplishing advanced space flight missions with vehicles where onboard human intelligence and operations are required. It will be a basic objective of the NASA to rationalize and refine the technology of manned space flight vehicles and associated systems, to achieve successful orbital flight and recovery of a manned satellite with an ICBM-booster and drag-reentry system, to evaluate the physiological and psychological effects of a space environment on man, to establish his capabilities and limitations for performing useful missions in space, and to devise and develop improved manned vehicles with increased capabilities for performing important advanced missions.

2. JUSTIFICATION

It is becoming increasingly evident that full exploitation of the potentialities of space flight for benefiting mankind will be dependent on the development of practical capabilities for operating manned space vehicles. While it may appear in principal that suitable instrumentation may be devised to perform increasingly complex space missions, in practice the availability in a vehicle of human intelligence and operational capabilities will prove to be the most effective method for successful accomplishment of many advanced space flight missions. In particular, he can contribute to the tasks of space exploration and utilization an observational, analytical, and decision making ability concerning both expected and unanticipated problems, and a vast flexibility of action for operation, correction, and maintenance of scientific and technological instrumentation and equipment that characterize his present usefulness in airplanes and the scientific laboratory.

In order to provide this capability a progressive program of research and development has been undertaken. A broad range of investigations directed to the solution of basic technological problems concerning vehicular configurations and construction, human factors, life support equipment and accommodations, launching systems, stabilization and control, reentry and recovery systems and techniques, operational and scientific instrumentation, and other vehicular subsystems has been initiated.

On the basis of extensive studies it has become evident that the first manned orbiting flight vehicle should be based on the use of an ICBM-booster launching system and the ballistic type of drag reentry into the atmosphere. The relative simplicity and reliability of this approach at the present state-of-the-art offers the best potentiality for early success and will yield a vehicle with a wide range of usefulness for investigating problems concerning both human and vehicular operation factors. This vehicle is also a logical steppingstone to larger systems of the same type with greater capacity for performing both scientific, civil and military services. In addition, it is adaptable to the investigation of both reaction-type space-path control and aerodynamic-lifting systems that will give later manned space vehicles a greatly increased scope of operations.

3. PROGRAM PHASING

During the fiscal year 1959, a wide range of studies and experimental investigations is being initiated to assess the problems that will be encountered in initial development and operation of manned space-flight vehicles and to establish the design requirements for the first operational vehicle. A contract for the design and construction of the full-scale manned capsule and associated instrumentation and equipment should be let early in 1959 and the initial capsule for preliminary investigations should become available approximately 9 months later.

Booster systems including solid-rocket clusters and liquid systems up to the ICBM size are being procured to provide for a progressive series of unmanned flights at increasing velocities up to orbital speed to refine both the vehicular systems and operational techniques to insure the safety of later manned operations.

Some of these preliminary flights will also utilize lower primates to assess a range of physiological and psychological factors that will be attendant to manned operation. Concurrently an intensive program of pilot training involving centrifuge, pressure chamber, simulator, and balloon experiments will be undertaken.

Further extensions of these programs are planned for the fiscal year 1960. During this period it is expected that the first orbital flights of the unmanned full-scale capsules will be achieved and effective techniques developed for the reentry and recovery phases of the operation. If the systems and techniques prove successful, some preliminary flights at suborbital speeds with the manned capsule may be undertaken. Additional vehicle capsules and boosters and associated equipment will be procured for the continuing manned flight experiments in the following year.

During the fiscal year 1960 it is also planned to undertake the development and construction of more refined versions of the vehicle that will offer greater capabilities for performing scientific investigations in space and for providing space path control. A range of analytical studies and model experiments will be undertaken to define the optimum approach to these problems and establish the basic design requirements. Initial development of appropriate vehicles should be undertaken.

The major items to be procured for this project are the satellite capsules. A total of 12 capsules will be delivered during the fiscal year 1960; fiscal year 1959 funds will be used for the design, engineering, and early construction phases of these satellites. Boosters for short-range test and qualification flights will also be purchased during the fiscal year 1959 and funds will be committed for the ICBM boosters required for the first orbital flights. The boosters for the manned orbital flights will be purchased in the fiscal year 1960.

7. PROJECT MERCURY TIMETABLE

The lack of a fixed date for launching man into space was referred to in testimony before this committee on April 9, 1959, by George M. Low, Chief of the NASA manned space flight program, and by Charles W. Mathews, Chief of the Space Task Group Operations Division.

Mr. MATHEWS. * * * As far as our development test program is concerned, we have a very vigorous wind tunnel program going on to make sure that our capsule aerodynamics are satisfactory. I have mentioned the landing tests. We also have escape tests going on at the present time.

The ballistic flights that will involve development tests will start about the middle of this year, and we will be getting the contractor to furnish capsules soon enough so that we can start qualifying them on Redstone * * * and Atlas, starting about the first of next year, and ultimately as we move along this will lead to manned flights on the Redstone and then on the Atlas.

* * * * * * *

Senator STENNIS. You mean sometime in 1960?

Mr. MATHEWS. As far as the manned flights are concerned, we will precede these as I mentioned by unmanned flights, and as we move along in the program we will decide that the situation is satisfactory for the man, and this will be decided at that time.

Mr. LOW. I would like to point out, Mr. Chairman, that there are many unknowns in this project, and we cannot predict exactly at this time when we will be able to fly a man.

Senator STENNIS. Yes.

Mr. LOW. It might come earlier than we hope for if everything goes real well, but the chances are that it would take a long time as yet.

Another factor bearing on such a timetable, the safety of the astronaut, was emphasized by Mr. Low in a NASA press conference on the astronaut program during which he stated:

* * * we will not send a man on the Mercury mission until we are convinced that the mission will be no more dangerous than certainly a normal test flying-type operation.

A reference to the safety factor problem was made by Dr. Dryden on February 20, 1959, when he appeared before this committee:

Senator STENNIS. * * *

You mention here that if you brought this manned vehicle down within 100 miles of your estimate, that would be considered fairly good aim. You have got a safety factor problem there, I know. Do you look upon that as very grave—if you can get it down to the earth you think you can handle the safety factor on landing?

Dr. DRYDEN. We must demonstrate that fact before we put a man up.

Senator STENNIS. Of course. That is not an insurmountable matter, is it, the safety factor?

Dr. DRYDEN. We don't think so. We have, of course, invited the cooperation of the military departments, the Navy, they are in this with us on the planning of it.

Senator STENNIS. Well, do you consider that a relatively minor matter?

Dr. DRYDEN. No; I don't consider it a relatively minor matter.

Senator STENNIS. You consider it a serious matter?

Dr. DRYDEN. I think it is a major matter, and this is one of the things that we will find out in the buildup, and this is one reason I didn't want to say definitely we know exactly when we are going to put a man into space.

PART II. PROJECT MERCURY SYSTEM

1. MERCURY CAPSULE

According to present plan, the Mercury space capsule will be mounted at its base on an Atlas rocket and serve as the payload of the powerful booster. The capsule will be conical in shape, about 6 feet in diameter at the base and 9 feet high.

On April 9, 1959, Maxime A. Faget, Chief of the Flight Systems Division of the NASA Space Task Group described the space capsule to this committee as follows:

Mr. FAGET. * * * the particular type of manned satellite that we have chosen is a ballistic reentry vehicle. What this means is that during reentry into the atmosphere, the vehicle does not use lift. It merely comes into the atmosphere without lifting and depends on atmospheric drag to decelerate it down to zero velocity, or near zero velocity for parachute deployment.

The reasons we chose this particular type of vehicle were as follows: Such a vehicle is considerably more compact and lighter than the more sophisticated lifting types of vehicles, and for this reason it was easy to incorporate it with an existing booster system, namely, the Atlas * * *.

This saved not only development time and expense, but it also enhances our chances of success, inasmuch as we are exploring the unknown with the least amount of new developments in proceeding in this manner.

Let's look a little more closely to some of the details of our space capsule. * * *

First, from a structural standpoint, the man is contained in a double wall pressure vessel shown in here. This pressure vessel will be made with a double skin of titanium, and it will be enclosed in a heat-protection vessel, the lower part of which is what we call a heat shield. This is a thick piece of material that absorbs the majority of the heat energy which is produced during reentry into the atmosphere. I should point out the capsule enters flying in this direction, with this large, heavy shield forward.

Now, like I say, this absorbs a majority of the heat energy. However, there is some heating in the rear portion which is taken care of by a very thin high-nickel alloy material which is capable of dissipating this heat by radiation out into space.

Between the heat-shielding material and the pressure vessel we have insulation which also serves as acoustical dampening material. In other words, we reduce the sound intensity from the booster during the boosting phase of the flight and will reduce the amount of aerodynamic noise during the entry, thereby making the flight more comfortable and enhancing the possibility of communicating with the ground station.

This multiwalled type of construction, I would like to point out, is also favorable from the standpoint of reducing the chance of a meteorite penetration of the pressure vessel. In other words, the outer shield and acoustic material will tend to slow these meteorites down, and we are fairly confident there is no chance at all of a meteorite penetration.

2. MERCURY BOOSTER VEHICLES

It is proposed that before orbital flight of the Mercury capsule is att mpted, it will be launched on ballistic paths of increasing range; initial short range ballistic flights will be made at NASA's Wallops Island Space Flight Center and longer range flights made at the Atlantic Missile Range. After ballistic and suborbital flights prove the system sound, orbital flights will be attempted. Some suborbital flights may be manned, but manned orbital flights would be undertaken only after repeated unmanned missions have proven successful.

At the present time, NASA's Project Mercury boosters include three basic vehicles. The variety of vehicles is accounted for by the fact that various segments of the Mercury operations can be tested by smaller or larger boosters, as the case may be, with resultant efficiency and economy of operations. Based on the unclassified information presented to this committee during hearings held in April 1959, the following booster vehicles are included in the Project Mercury testing program.

Little Joe

This is a cluster of four solid propellant Pollux or Castor rockets and four solid propellant Recruit rockets housed in a cylindrical section with a total of up to 250,000 pounds of thrust at launching; it is used in research and development tests and in qualification tests at Wallops Island.

The Little Joe vehicle can boost a full-scale capsule to about 4,000 miles an hour and has a range of almost 130 miles. Costing about one-sixth the price of an Atlas, this vehicle is of value in simulating escape conditions in separating the escape capsule, for determining maximum load conditions, and in low-speed reentry tests where the vehicle is projected out of and returns into the atmosphere.

NASA has scheduled six Little Joe shots during the latter half of 1959 and spring of 1960. The majority of the Little Joe shots will employ boilerplate versions of the Mercury capsule.

A test series of Little Joe booster flights was begun in October 1959 at NASA's Wallops station. The first flight, on October 4, was a proof test of the eight-engine launching vehicle system, using Pollux and Recruit rockets. The second flight, on November 4, used only two of the four Pollux engines in addition to the four Recruits and successfully provided data on: (1) performance of the escape system under maximum load conditions; (2) design concepts of the capsule; (3) further qualification of the Little Joe booster-capsule combination; and (4) operation of the recovery parachutes. A 40-minute flight up to speeds of 3,600 miles per hour on December 4 successfully tested the capsule's escape system at a high altitude (55 miles). A secondary test involved the successful inclusion of a monkey in the capsule during flight.

Redstone

The Redstone vehicle is used in qualification tests and will be the first vehicle used in astronaut-piloted operations. The Redstone capsule combination will first be qualified through unmanned and animal flights. This liquid propellant vehicle has a high record of reliability. It develops approximately 75,000 pounds of thrust, has a range of about 150 miles, and a speed of about 4,000 miles an hour. The Redstone will be fired from Cape Canaveral, Fla., and operate on the Atlantic Missile Range.

Eight Redstone shots have been tentatively programed by NASA for calendar year 1960. During Redstone capsule flights the astronaut's ability to control the attitude of the capsule will be checked, and he will also be subjected to high launch accelerations, to about 5 minutes of weightlessness, and also to high reentry deceleration.

Atlas

It is proposed that this largest booster to be used in the Mercury vehicle development and qualification testing program will also be used in the final Mercury orbital flight. George Low of NASA stated before this committee on April 9, 1959:

Only the Atlas can complete the orbital mission; only the Atlas can get the satellite into orbit.

The liquid propellant Atlas, capable of developing a total of about 380,000 pounds of thrust, will first be used in a range of 2,000 miles from Cape Canaveral, at a speed of about 17,000 miles per hour. Test flights of the Atlas will be unmanned; only the orbital flight of the Atlas will contain an astronaut. NASA has scheduled 10 test firings of the Atlas, beginning in the last half of calendar year 1959 and extending through 1961. Atlas tests include Big Joe firings of boilerplate capsules to orbital speed but reentering the atmosphere rather than going into orbit; the capsule's reentry will test severe heating conditions associated with orbital speed and their effect on the capsule's heat shielding. Finally, the Atlas would be used to place the Mercury capsule in orbit.

A successful Big Joe reentry and recovery flight was made on September 9, 1959. The primary research objectives met on this flight were: (1) to determine the performance of the ablation heat shield and to measure the afterbody heating of the capsule; (2) to determine the flight dynamic characteristics of the capsule; (3) to evaluate the forces on the capsule during flight and the operation of the control system; (4) to effect capsule recovery and to establish the adequacy of the recovery aids used in the capsule; and (5) to check procedures used in the recovery operation. Since the first Big Joe test achieved all technical objectives, the second test was cancelled.

3. MERCURY FLIGHT TEST PROGRAMS

Orbital flight of the Mercury manned space capsule would be preceded by a buildup of vehicle capabilities and scientific data. The flight test programs include:

1. Development tests of full scale boilerplate test capsules covering design criteria, components, and component reliability. These tests will establish design criteria to guide the manufacture of the final capsules, aid in the capsule's component development, and help insure the reliability of the final capsule system.
2. Qualification tests involving all final hardware, the capsule, and the equipment on board. Included will also be a series of animal flights which will represent a "biological test bed" to give the answers to these questions: (*a*) is the life support system adequate and reliable to meet the known metabolic requirements?; (*b*) are the dynamic force stresses imposed as predicted?; and (*c*) does the protective equipment (couch and restraints) maintain these force-effects within the range of physiologic tolerance?
3. Pilot missions in ballistic flight to train pilots and aid in their qualification for orbital flight through the performance of tasks during ballistic flight to increase the reliability of the mission.

Air drop tests of capsule recovery system

The terminal phase of the Project Mercury flight—safe recovery after the capsule reenters the atmosphere—was an initial consideration of space scientists. Theoretical and experimental studies of this problem were considered by scientists of the NASA-Langley

Pilotless Aircraft Research and the Flight Research Divisions some months before the Space Task Group was formed.

The Mercury capsule will be wingless and to bring it safely and stably to earth two parachutes will be employed, with another in reserve for emergency use. The first (or drogue) is a small ribbon parachute that will open at an altitude of about 70,000 feet. This drogue will trail the capsule and prevent tumbling, and at about 10,000 feet will drag out the second (or recovery) parachute. The recovery chute, 62 feet in diameter, will lower the capsule to water or ground. If the primary parachute fails to be ejected, another full-scale recovery chute will be released. Both automatic and manual release mechanisms are provided. Investigations are being made to test snatch and shock forces involved in parachute releases at high altitudes. Motion pictures and telemetry record performance data.

Essentially, the air-drop program is designed to tell scientists the optimum altitude at which to deploy the recovery parachute; reliability of the parachute system; motions which can be expected during descent; impact forces in both water and ground landings; and reliable methods of recovery after landing. Before tests began at Wallops Island in the fall of 1958, NASA scientists developed methods for dropping a full-scale model capsule from its carrier, a large transport airplane, during the late summer over drop zones at Fort Bragg, N.C. and over a small airfield at West Point, Va.

Full scale 1-ton models used as test vehicles are staged out of Langley, where capsules are loaded on a transport airplane loaned to NASA by the USAF Tactical Air Command. The test vehicle is dropped into a free fall and is photographed in its descent by two chase planes. One chase aircraft is stationed at the same altitude as the carrier transport plane, and the other at the altitude where the recovery parachute will be deployed. When the capsule lands, two helicopters and a crash rescue boat go to the impact spot. One helicopter, directed by the other and the crashboat, retrieves the capsule by shackling a line to an eye located on top of the test model.

Detailed studies of the entire operation are made from motion-picture films taken by the jet airplanes.

Testing of escape system for launching phase

When the Mercury capsule is launched, it will have on top of it a pylonlike arrangement tipped with an escape-rocket system. If the booster malfunctions at any time from pad to staging, an escape rocket can be triggered and it will carry the capsule and its occupant away from the booster. Normal recovery by parachute then will take place.

The escape system was described by Maxime A. Faget, Chief of the Flight Systems Division of the NASA Space Task Group, before this committee on April 9, 1959, as follows:

We are using the Atlas booster, which is the one that is available now, and indications are that even when we are ready to launch Mercury the Atlas will not be completely reliable. There is certainly a small chance of failure of the rocket. For that reason, we have provided a means for the pilot to escape from the vicinity of the rocket motor during the boosting phase of the flight.

This is accomplished with a small rocket motor mounted on a tower-type arrangement at the front end of the capsule. In the event of an impending failure, which can be sensed with various instrumentation on the booster, or on the ground with our tracking and launching complex, the abort system will be triggered. This will fire the escape rocket and will pull the capsule away from the booster at a velocity of again around 350 miles an hour relative to the booster. As a matter of fact it will put 250 feet between the escape configuration and the booster during the first second, which is more than enough to get it out of any danger.

After the escape rocket is fired the tower will be jettisoned; after it is jettisoned the attitude is not stable, so that the capsule will turn around. After the attitude changes, the parachute is deployed, and the landing and recovery would be made in the normal manner.

Reliability tests of the escape system, and aerodynamic studies of the capsule-escape combination, are being conducted from NASA's Wallops Island launching site. With use of full-scale models, scientists are determining proper alinement of escape-rocket nozzles as well as dynamic forces on the capsule and escape arrangement during launch and descent.

Simulating flight conditions in wind tunnel tests of scale models

Behavior of the capsule during flight is being studied at the Langley and Ames wind tunnels and at the Air Force Arnold Engineering Development Center, Tullahoma, Tenn. Free-flying model studies are being conducted at Wallops Island for the same purpose.

At Wallops, small models are subjected to the full velocity range to investigate tumbling characteristics, reentry dynamics and afterbody heating. For these studies, capsule models are placed on the tips of research rockets.

In its extensive wind tunnel program, the NASA uses the complete range of scaled-down capsule-booster combinations planned in the buildup program. For example, buildup flights will be held with the capsule atop Redstone booster: wind tunnel research is providing answers to control inputs and trajectories by investigating the lift, drag and static stability of the Redstone-Mercury arrangement in scale models.

At Langley, scientists are employing wind tunnels to determine heat transfer and pressure of the heat shield, dynamic stability, afterbody pressure distribution, and lift and drag. The Langley tunnels cover the velocity spectrum from just a few miles per hour to Mach 18 (11,000 miles per hour).

At the Ames Research Center, Moffett Field, Calif., wind tunnels are used to study panel flutter, pressures and heat transfer, static and dynamic stability plus lift and drag in the Mach 0.6 (390 miles per hour) to Mach 15.3 (9,950 miles per hour) velocity range.

Lift, drag, stability and pressure distribution studies in the speed range of Mach 0.5 (325 miles per hour) to Mach 20 (13,000 miles per hour) are scheduled at the Arnold Center.

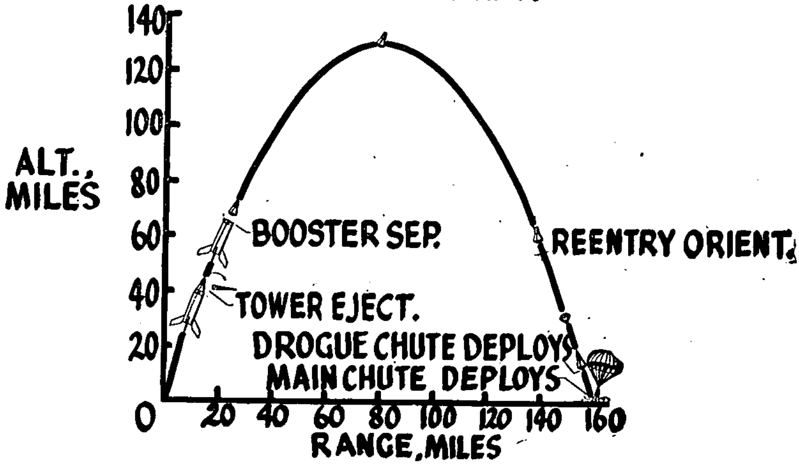
Testing impact of capsule after orbital flight

When the Mercury capsule descends after its orbital flight, it will fall with a velocity of 30 feet per second. Drop tests at this velocity in the water tank facilities at Langley have shown that a safe water reentry can be made with the presently shaped leading face on the capsule. In the event of a ground landing, scientists are conducting studies into a crushable material which can absorb the landing shock. Materials now under study include honeycombed arrangements of corrugated plastic and aluminum, as well as the more fibrous cellulose materials. In these tests, scientists are dropping instrumented models in water tanks and on hard surfaces from all impact angles, using a variety of materials and arrangements.

LITTLE JOE PROGRAM

OBJECTIVES
- ESCAPE SYSTEM CHECK
- REENTRY DYNAMICS EVALUATION
- DROGUE CHUTE STABILITY EFFECTIVENESS

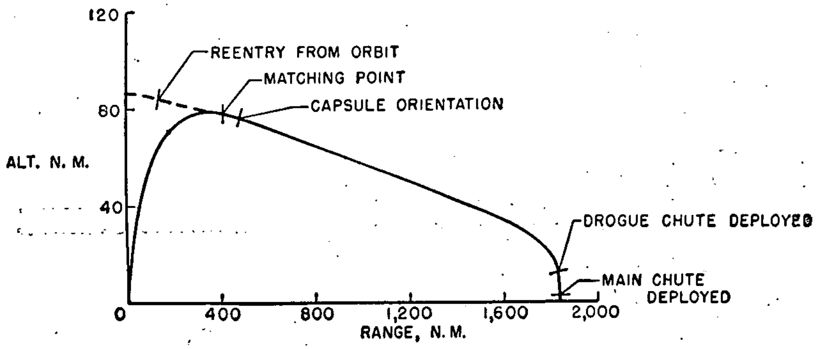
TYPICAL FLIGHT PLAN

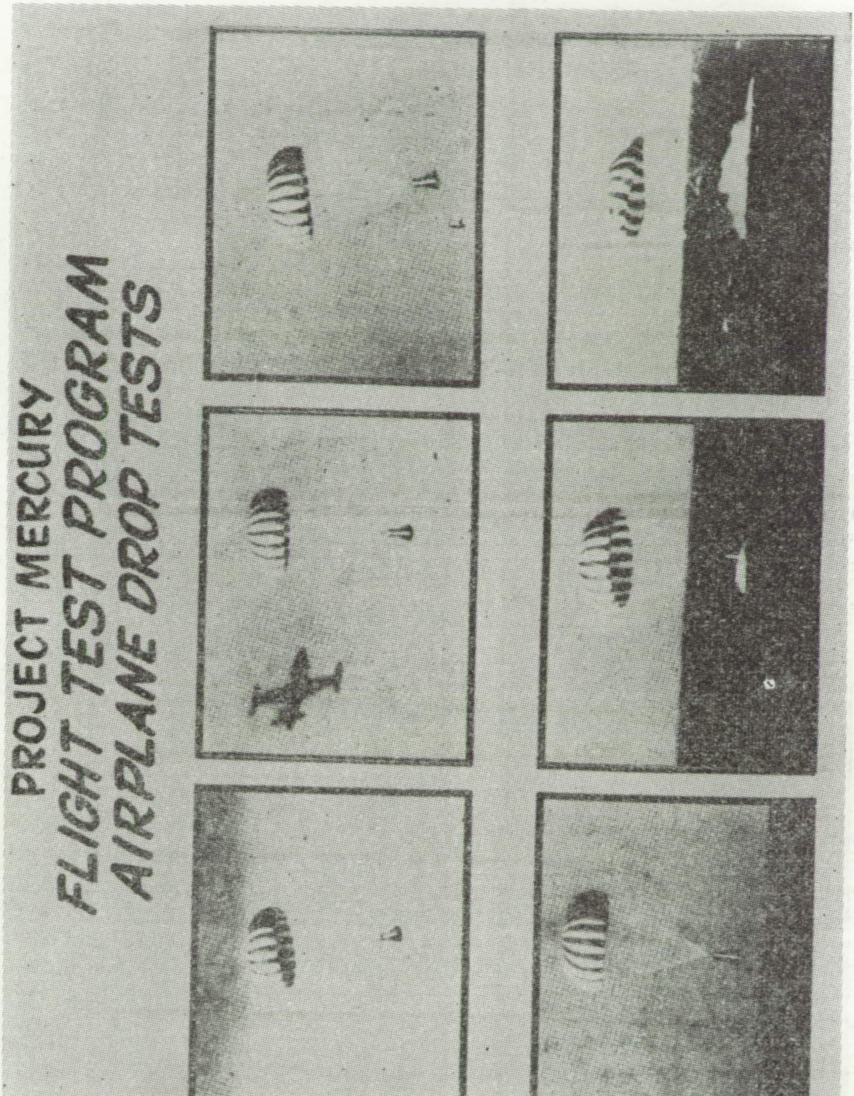


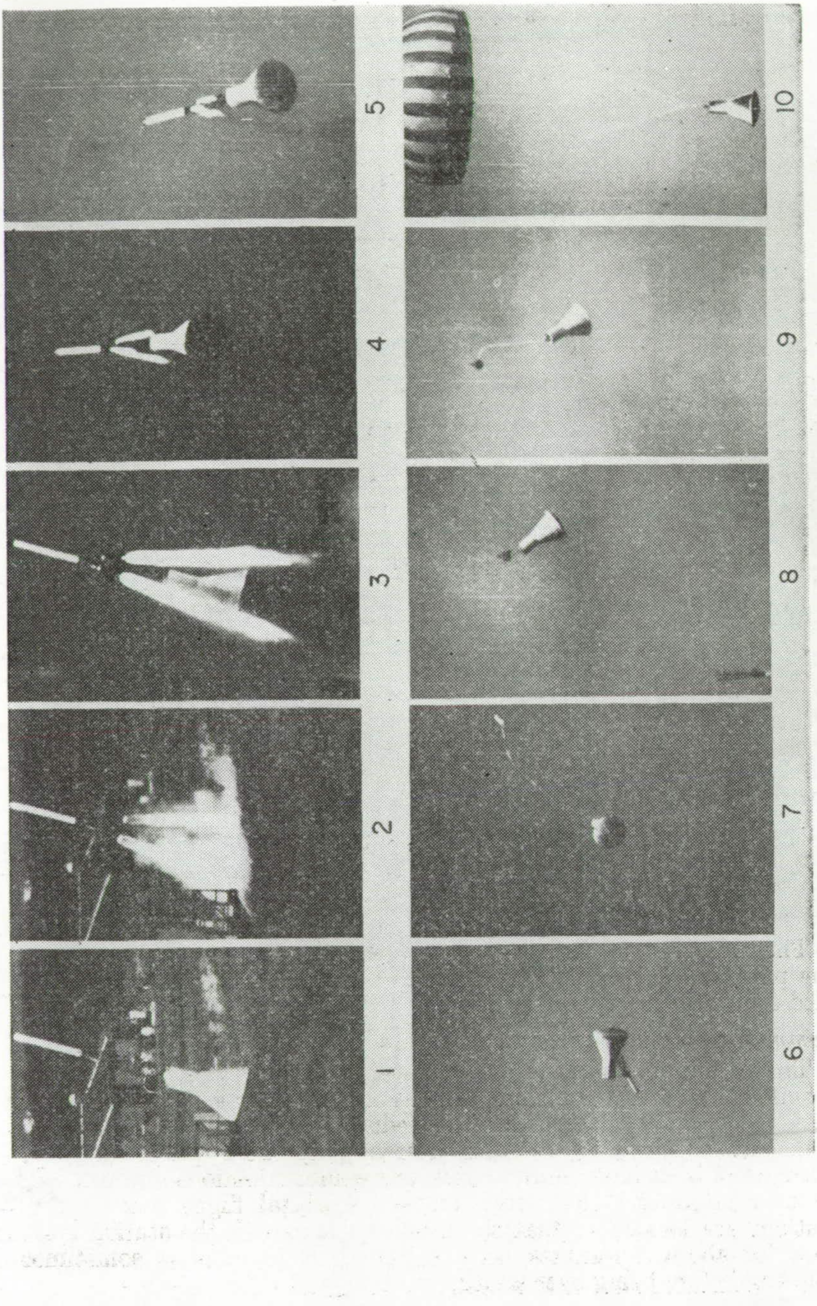
ATLAS BOOSTED REENTRY TESTS

OBJECTIVES
- ABLATION HEAT SHIELD BEHAVIOR
- CAPSULE AFTERBODY HEATING
- REENTRY DYNAMICS
- LAUNCH AND RECOVERY EXERCISE

FLIGHT PLAN




PROJECT MERCURY
FLIGHT TEST PROGRAM
AIRPLANE DROP TESTS



Mercury capsule escape system test.

PART III. PROJECT MERCURY ORBITAL FLIGHT OPERATION

1. LAUNCHING THE MANNED SPACE CAPSULE

It is expected that the Mercury capsule will be launched from Cape Canaveral in a direction slightly north of due east over the Atlantic Ocean. The general configuration of the Mercury system consists of the Atlas booster, the conical manned capsule atop the booster, and an escape rocket mounted on a towerlike pylon structure above the capsule. The capsule will contain the astronaut on his supporting couch which is designed to minimize the effects of high acceleration loads on the pilot, the environmental or life-support system, the attitude-control system, pilot displays, communications, and instrumentation. The cylindrical upper part of the capsule contains a drogue parachute, for stability, and a main parachute for recovery.

The Atlas booster is a configuration of three engines, two outer 150,000-pound thrust booster engines and an 80,000-pound thrust inner sustainer engine. During the staging period of the launching the three burning engines will lift the vehicle to a height of about 50 miles at which time the two booster engines will drop off and the sustainer engine will continue to boost the vehicle to orbital velocity. Shortly after staging, the escape tower, no longer needed outside the atmosphere, is also jettisoned.

When the vehicle achieves orbital velocity and altitude, 100–150 miles above the earth at about 18,000 miles per hour, the capsule will be separated from the booster by small separation rocket motors. After separation, the capsule will change its attitude 180°, from the direction of the booster to the opposite direction, so that the heat shield will be in front of the capsule when it reenters the atmosphere. The capsule will continue in this direction until it has made the presently scheduled number of three orbits around the earth. The Mercury tracking network has been augmented so that if it is necessary to bring in the capsule after one orbit it would be possible to do so.

2. THE ASTRONAUT'S DUTIES DURING ORBITAL FLIGHT

The reliability of the Mercury mission can be increased through the participation of the astronaut pilot including the following scheduled activities.

Communicating with ground stations

The communication system will allow the astronaut to maintain ground contact. At launching a series of ships will be deployed in the Atlantic Ocean for purposes of immediate down-range tracking and, if necessary, for recovery of the astronaut in the event of an abort during the launching phase. Mercury communications stations will be located around the world along the orbital flight paths. The stations are located so that the pilot can talk with the station he is over for about 5 minutes, with a period of 10 minutes sometimes elapsing before being over another station.

Making scientific observations

A well-qualified pilot can make valuable scientific observations unobscured by the atmosphere, including observations about the earth, the stars, and other planets, and about cloud cover and other meteorological considerations.

Monitoring onboard equipment

The astronaut will monitor equipment to insure that it is working properly, and if not, to initiate emergency procedures.

Controlling capsule attitude

The capsule's attitude control system consists of minute rocket motor jets employing hydrogen peroxide as a propellant. These roll, pitch, and yaw control jets operate in response to an autopilot which is directed by a horizon scanning system which is sensitive to infrared rays and is capable of sensing the horizon and directing the autopilot as to which way is up, thus always keeping the capsule stable. When the capsule is in orbit the pilot will be in a sitting position with the earth below. The capsule also has a periscope, so arranged to optimize the earth's display, and a manual control system similar to the autopilot system that the astronaut can use to stabilize the capsule's position and keep himself upright.

Navigating, and firing retrorockets

It is expected that the astronaut will be able to predict where he is going to be so that he can determine the point at which to fire the retrorockets. When the capsule makes its final orbit the retrorockets will be fired somewhere between Hawaii and the west coast of the U.S. mainland. The retrorockets will reduce the speed of the capsule by about 350 miles per hour, less than the velocity required to keep it in orbit. The rockets will be jettisoned just before the capsule reenters the atmosphere over Florida. The capsule reenters the atmosphere in a ballistic manner where air drag on the capsule reduces its forward velocity. Just prior to the time the capsule decelerates to sonic speed a drogue parachute is deployed to stabilize the capsule attitude during the transonic and subsonic portion of the flight. When the capsule has decelerated to a speed of about 250 feet per second, at an altitude of approximately 10,000 feet, the main recovery parachute will be deployed to lower the capsule to the ocean surface.

Initiating emergency procedures

The astronaut will have backup provisions to escape if he determines this necessary, or to deploy the landing parachute if he decides that the automatic deployment system is not functioning properly. In the event of a booster malfunction at any time up to Atlas staging, the escape rocket will be fired to remove the capsule from the booster vicinity. After the capsule coasts to its peak altitude, the escape rocket will be jettisoned; the capsule will be reoriented, and will go through the normal sequence of reentry, drogue parachute deployment, main parachute deployment, and recovery. At times between Atlas staging (escape-rocket jettisoning) and orbital injection, the capsule will be separated from the Atlas, the retrorockets will be fired, and the normal entry and recovery will be gone through.

8. TRACKING AND RECOVERING THE MANNED SPACE CAPSULE

Because there is no direction of control over the Mercury capsule after it reenters the atmosphere it must be tracked with sufficient accuracy so that landing location can be predicted and recovery groups alerted.

NASA and the Department of Defense have established a joint working group on search and recovery aspects of the Project Mercury program which will involve facilities of the Army, Navy, and Air Force.

On April 8, 1959, Francis B. Smith, chief of NASA's tracking programs, described the tracking requirements of the manned satellite program to this committee as follows:

> The requirements of this program are particularly severe for at least two reasons; one being that there is a man aboard and the reliability of the tracking facilities and control facilities must be as near perfect as they can humanly be. The second is that this satellite, unlike most of the others launched to date, will not remain aloft for a very long period of time. Present plans call for launching it northeastward from Canaveral and allowing it to go around once, twice, and possibly three times, and then for a recovery in the Atlantic area.
>
> In tracking of the more usual type of earth satellite, it normally requires a few orbits, two or three or four, before the orbit can be thoroughly established; but in this case it will be essential to establish the orbit immediately once it is injected, so that you know exactly where the vehicle is going and exactly where it will come down. For these reasons, additional facilities are required.

The major considerations involved in choosing an orbit for the Mercury capsule were: (1) In the critical reentry and landing path phase, to maximize the use of existing tracking radar facilities in the southern part of the United States; and (2) that both launch and recovery would take place at the Atlantic Missile Range, where launching, guidance, control communications, telemetry, and range safety could be utilized.

Facilities do not now exist in certain large areas of the world for the tracking and control that is essential to the safety of the Mercury astronaut and capsule or for telemetry and communications with the astronaut. Equipment will be assembled to provide telemetry and communications links with the capsule and determine its position and velocity. Such devices must be capable of monitoring the onboard equipment of the capsule, the life-support system, the physiological reactions of the astronaut, and the reentry command equipment, as well as maintaining communications with the astronaut during orbital flight. Ground support facilities for Project Mercury will include the following locations:

1. Existing or already-planned Department of Defense equipment at the Atlantic Missile Range, Hawaii, Pacific Missile Range (southern California), White Sands Missile Range (New Mexico), and Eglin Air Force Base (northern Florida).
2. Use of existing Australian tracking stations in Woomera, Australia, plus an additional transportable tracking radar on the western coast.
3. Establishment of a permanent instrumentation and tracking facility on Bermuda, as well as additional transportable tracking radar.
4. Additional transportable tracking radars will be installed on Bermuda and on the west coast of Africa to track the capsule in the event an abort becomes necessary during the launch phase.

In this event, the capsule would not go into orbit and would have to be recovered between Bermuda and the African coast.

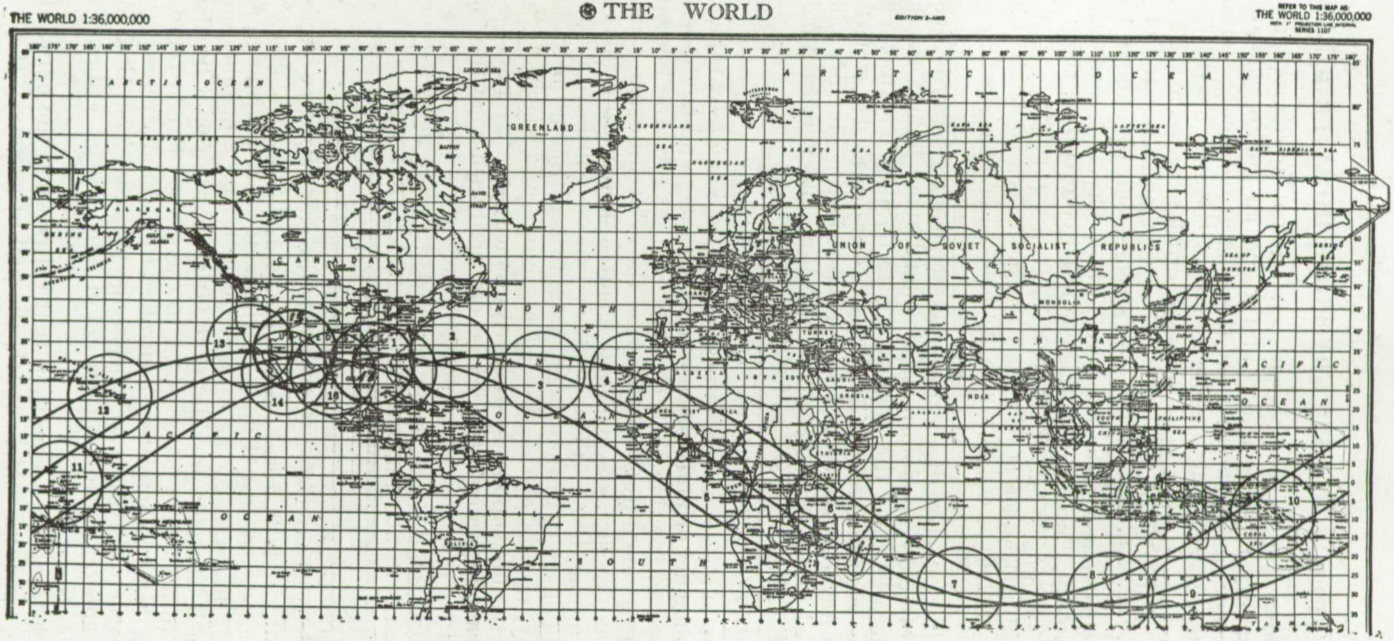
5. Establishment of transportable tracking and communications stations in the Canary Islands, western Australia, Central America, and southern Texas.

6. Establishment of transportable or shipboard communication and telemetry stations in the Atlantic Ocean, Indian Ocean, southwest Africa, southeast Africa, and Canton Island.

Except for the Bermuda station, additional facilities will be transportable (either van mounted or shipborne), both for purposes of economy and to permit easy relocation for later phases of Mercury or other future space programs.

NASA has indicated the possibility that, instead of completing three orbits before recovery, it might become necessary to bring the Mercury capsule in after only one orbit. This would require the location of an additional transportable tracking radar in West Central America to track the capsule during reentry after one orbit.

PROJECT MERCURY TELEMETRY AND VEHICLE COMMUNICATIONS



1. Cape Canaveral.* 2. Bermuda.* 3. Mid-Atlantic ship. 4. NW. Africa.* 5. SW. Africa. 6. SE. Africa. 7. Indian Ocean ship. 8. West Australia.* 9. Woomera, Australia.* 10. Deleted. 11. Canton Island. 12. Hawaii.* 13. Southern California. 14. Central America.* 15. White Sands, N. Mex. 16. South Texas.* 17. Eglin AFB, Fla.*

NOTE.—All stations have telemetry and voice communications with the capsule. Stations marked * also have tracking capability.

PART IV. PROJECT MERCURY BIOMEDICAL PROGRAMS

The various biomedical programs undertaken in connection with Project Mercury are also aimed at the overall guiding philosophy of the Mercury undertaking: That there be an adequate margin of safety for the Mercury astronauts and that the risk hazard should be no greater than in test pilot operations with experimental aircraft. Brig. Gen. Don D. Flickinger, staff surgeon and Director of Life Sciences in the Air Research and Development Command Headquarters, Department of the Air Force, who is closely associated with Project Mercury, stated before this committee on April 9, 1959:

> * * * We attain this degree of safety for our astronauts by a very rigid selection, test, and qualification of both the hardware components involved in the safety of the astronaut, and of course, the human component as well. Both are equally important.

General Flickinger went on to mention some of the hazards involved in Project Mercury, the information at hand about human tolerances to these hazards, and the engineering techniques and methods of maintaining such hazards within known tolerances. He stated that the factors for crew safety and effectiveness in the Mercury mission were divided into two groups: critical factors and uncritical factors. These are listed and defined as follows:

Critical factors for crew safety and effectiveness

1. Dynamic forces: Forces imposed upon the human by the vehicle itself in achieving orbital velocity and in reentry and landing.
2. Life support system: All components that give the human the basic requirements during the period of the orbital mission, including food, water, pressure, oxygen, and maintain potential noxious gases below the atomic level. (The Mercury capsule will have a 100 percent margin of safety in that it can sustain the astronaut for 48 hours, if necessary, instead of the planned maximum of 24 hours.) Many aspects of the life support system requirements are minimal because of the short duration of the flight as compared with what they would have to be for extended space travel.
3. Medical monitoring: To know how the human being is functioning and also how the equipment furnishing his vital needs is functioning.

Uncritical factors for crew safety and effectiveness

These factors have been referred to as the great mystery of manned space flight, because they cannot be fully duplicated, apart from experiencing actual orbital flight. The factors are considered as uncritical only in terms of the Mercury vehicle and scheduled mission profile which basically provides that (*a*) should the pilot be disabled or unable to perform when exposed to the altered force environment the vehicle can be completely controlled by ground stations, (*b*) the orbital apogee will remain well below the proximal Van Allen lobe of radiation, and (*c*) maximum duration of time in orbit will not exceed 18 to 24 hours.

1. Weightlessness: A condition that exists when the outward centrifugal force of the vehicle equals the pull of gravity. It does not

appear to be a handicap for short-term manned flight, but long-range flight could be more serious in resultant physiological changes.

2. Isolation and confinement: The psychological aspects on the individual of isolation, confinement, and complete separation from all terrestrial things.

3. Cosmic radiation: The Mercury orbit is approximately 100 to 150 miles above the earth, below the hazards of the great radiation belts that affect deeper space probes. From known measurement a Mercury pilot in orbit for even as long as 48 hours would receive about 45 milliroentgens of radiation, which is well within the tolerance dose.

PROJECT MERCURY
FACTORS IN CREW SAFETY & EFFECTIVENESS

DYNAMIC FORCES (G)
- ROCKET SLEDS
- CENTRIFUGE
- EJECTION TOWERS
- SPIN TABLE

LIFE SUPPORT SYSTEM
- CAPSULE SIMULATOR
- MAN HIGH CAPSULE
- SUBMARINE
- PRESSURE SUITS

MEDICAL MONITORING
- MAN HIGH FLIGHTS
- X-15 PHYSIOLOGIC TELEMETRY
- BIOLOGIC SPACE EXPERIMENTS

WEIGHTLESSNESS
- PARABOLIC FLIGHT
- PARTIAL SIMULATION

ISOLATION AND CONFINEMENT
- GROUND SIMULATION
- MAN HIGH FLIGHTS

COSMIC RADIATION
- BALLOON PLATFORM
- SPACE PROBES

DYNAMIC FORCES

PHASE	G-MAX. PREDICTION	G TOLERANCES	TEST EQUIPMENT
NORMAL LAUNCH	9	23	HUMAN CENTRIFUGE
PAD ESCAPE	17	29	HOLLOMAN TRACK
HIGH "Q" ESCAPE	-5	29	HOLLOMAN TRACK
EMERGENCY	18	25	JOHNSVILLE CENTRIFUGE
NORMAL REENTRY	9	16	CENTRIFUGE
LANDING IMPACT	16-22	50	HOLLOMAN TRACK

LIFE SUPPORT SYSTEM

REQUIREMENTS FOR 24 HR CAPSULE ENVIRONMENT	COMPONENTS	TEST EQUIPMENT
TOTAL PRESSURE 5 P.S.I.	O_2 BOTTLES 3000 P.S.I.	MAN HIGH FLIGHT SINGLE - 32 HOURS TOTAL - 105 HOURS
TEMPERATURE 65°-80°F.	HEAT EXCHANGER	
OXYGEN ~4 P.S.I.	PRESSURE REGULATOR	ALTITUDE CHAMBER TEST - 48 HOURS
CO_2 MAX. 0.16 P.S.I.	LiOH SCRUBBER	
HUMIDITY ~0.2 P.S.I.	HEAT EXCHANGER	SUBMARINE 60×100 MAN DAYS

EMERGENCY PROVISIONS

100% MARGIN IN CAPSULE

PRESSURE SUIT - 120 MINUTES - PROVIDES O_2, PRESSURE, COOLING

MEDICAL MONITORING FOR CREW SAFETY

REQUIREMENTS	METHOD	TEST EQUIPMENT
CARDIO-PULMONARY FUNCTION	EKG RESPIROMETER O_2 RATE BLOOD PRESSURE	CHAMBERS MAN HIGH X-15/XF 102
PERFORMANCE	TASK RESPONSE	CHAMBERS-SIMULATORS
CONSCIOUSNESS	VOICE REPORTING TASK RESPONSE	ROCKET SLEDS
THERMAL	BODY AND CAPSULE THERMOCOUPLES	CENTRIFUGES
ENVIRONMENT	PRESSURE RECORDINGS TOTAL, O_2 REMAINING WATER VAPOR TENSION CO_2 DIFFERENTIAL	ANIMAL PROBES & SATELLITES

BIOMEDICAL FACTORS – SPACE ENVIRONMENT
(NOT CRITICAL TO CREW SAFETY)

CONDITION	TEST EXPERIENCE	DURATION	RESULTS
WEIGHTLESSNESS	AIRCRAFT-PARABOLIC FLIGHT PATH	20-80 SECS	NO EFFECT
	ANIMAL BALLISTIC	5-12 MIN	NO EFFECT
	LAIKA - ORBITAL	7-10 DAYS	NO EFFECT REPORTED
COSMIC RADIATIONS PRIMARY	HUMAN AND ANIMAL BALLOON	24-48 HRS	NO IMMEDIATE EFFECTS
	"PIONEER" MEASUREMENTS	45 MR/48 HRS	BELOW AEC TOLERANCE DOSE
PSYCHOLOGICAL ASPECTS (ISOLATION & CONFINEMENT)	VOLUNTEERS-SIMULATORS	5 DAYS	NO EFFECT
	MAN HIGH FLIGHTS	10-30 DAYS	NO EFFECT

Mercury astronaut pressure suit

On July 24, 1959, NASA selected a modified U.S. Navy pressurized flight suit as the life-support garment to be worn by the Project Mercury astronauts in manned orbital flight. Selection of the suit came after more than 6 months of intensive testing and evaluation of three different pressure suits. The Navy suit is made by the B. F. Goodrich Co., Akron, Ohio. NASA ordered 20 of the suits, the total cost of which is expected to be about $75,000.

Under the one-piece flight suit, the orbiting astronaut will wear a double-walled rubber ventilated garment of a type used by Air Force pilots. The inner wall of this suit will be perforated to permit the body pores to "breathe." Air will flow into the inner suit through a waist connection, circulate through the suit and be exhausted through a pipe in the helmet. The air then will move through an air-conditioning system under the astronaut's couch where impurities will be removed before it is recirculated.

The outer suit features body, leg, and arm lacings. The headgear, which locks to the suit on a neck ring, looks like a football helmet with a plastic facepiece. As in modern fighter aircraft, the outer suit—a single layer of reinforced rubber—will be pressurized only if the capsule pressure fails. It will serve as a backup safety feature. Should anything go wrong with the capsule pressurization, the astronaut will have the pressurized suit to fall back on.

The suit will be coated with a silver spray which is to act as an additional heat buffer and a radiation shield.

PROJECT MERCURY ASTRONAUT PRESSURE SUIT

Factors in the suit decision—made by a six-man NASA selection board which included Astronaut Walter M. Schirra—were: mobility, compactness, reliability, resistance to temperature, pressure integrity and ease of getting in and out of it. At Wright Air Development Center and McDonnell Aircraft Corp., NASA prime contractor for the Project Mercury capsule, rigorous suit evaluation tests were carried out. Test team members spent as long as 24 hours in the suits to check mobility and the fitting. Temperatures up to 180° F.—much in excess of the temperatures the astronaut is expected to encounter in flight—were applied for more than 2 hours at a time. In addition, tests were made in a whirling centrifuge pulling as many as 8 G's. Sound reduction features also were carefully gaged.

It is planned that the astronauts will wear the suit in the suborbital Redstone-boosted Mercury test flights as well as the Atlas-boosted orbital flights.

Biomedical space tests significant to Mercury program

On May 28, 1959, the United States successfully launched biomedical experiments as a secondary mission in the nose cone of a Jupiter intermediate range ballistic missile. Essential information was sought about such space flight problems as launch and reentry stresses and weightlessness. The experiments were provided by the Surgeons General of the Army and the Navy and were performed in support of the space programs of the National Aeronautics and Space Administration.

The missile was programed for about 1,500 miles, with maximum altitude of 300 miles. The trajectory provided a gravity-free or weightless state for about 9 minutes. A recovery of the nose cone was made. The four experiments included:

1. Monkey Able, a 7-pound American-born rhesus monkey, performing a psycho-behavioral test. The monkey was to attempt a behavioral response throughout the flight—the rapid pressing and releasing of a modified telegraph key—marking the first time this has been attempted during extended weightlessness.

2. Monkey Baker, a 1-pound squirrel monkey in an experiment similar to one performed in December 1958. (Important scientific data were obtained about the physiological reactions of the monkey although recovery of the nose cone was unsuccessful.) By electronic circuits, measurements were made on Monkey Baker of its respiration, body temperature, pressure within the capsule, and heart action.

3. Biological experiments, primarily for radiation studies, involving various cellular systems such as possessed by yeast, corn, mustard seeds, fruitfly larvae and human blood.

4. A mold spore and egg fertilization experiment to determine effects of space phenomena such as radiation and weightlessness on cell division and the fertilization process.

The experiments were conducted on a space available basis, without interfering with the Jupiter ballistic missile development program. Data from the experiments were made available to NASA and the military services. Other Government agencies or institutions involved in biomedical research received the same information upon request.

The Ballistic Missile Agency of the Army Ordnance Missile Command developed and launched the Jupiter, and provided most of the

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hardware and instrumentation associated with the projects. The Navy Surgeon General prepared the squirrel monkey experiments in conjunction with the Army. The cooperative Army-Navy biomedical experiments, conducted in support of the National Aeronautics and Space Administration's space program, were aimed at providing additional information about space flight.

Medical factors involved in Mercury astronaut selection

1. *Physical fitness.*—Immediately following their Washington interviews the candidates were assigned to groups, five of six men each and one of two. One group at a time reported to the Lovelace Clinic in Albuquerque, N. Mex., for an exhaustive series of examinations. The other men returned to their home stations to await the call for their groups. The first contingent entered Lovelace February 7, and the others on succeeding Saturdays. Each candidate spent 7½ days and 3 evenings at the Lovelace facility.

General physical requirements were established by the NASA Life Sciences Committee; since all those examined were active test pilots it was not anticipated that any would be disqualified as physically unfit. Rather, degrees of physical soundness were obtained and evaluation was dependent upon a comparison of each man to his fellow candidates.

To establish a comparative yardstick, the Lovelace program began with a complete aviation and medical history extending to the following areas:

Hematology and pathology (blood and study of tissues).
Roentgenology (X-ray consultations).
Ophthalmology (eyes).
Otolaryngology (ears, nose and throat).
Cardiology (heart and circulation).
Neurology and myology (nerves and muscles).
General internal medicine.
Related laboratory studies.

Special consultations were provided if indicated by the candidate's medical history or any of the general examinations. These examinations were given under normal clinical procedures, while the subject was in a resting condition.

Results were recorded on special computing cards developed by the Lovelace Clinic for the astronaut program. These cards are mark-sensed so they may be read directly by the examining physician and contain the candidate's complete aviation and medical histories and examination findings.

2. *Psycho-physiological stress testing procedures.*—A determination of the candidate's psychological makeup and an estimate of his ability to cope with stresses was made.

The Air Force, with the assistance of Army and Navy specialists, conducted psychological and stress measurements at the Wright Air Development Center Aeromedical Laboratories. The examinations were in these general areas:

(*a*) Psychiatric evaluation, psychological testing, anthropometric studies.

(*b*) Stress tolerance determinations to: Thermal flux, accelerative forces, low barometric pressures, pressure suit protection, isolation and confinement.

(*c*) Final clinical appraisal of suitability.

Testing at WADC was conducted with candidates in six groups of five men each and one group of two. The first group entered February 15; each man was evaluated 6 days and 3 evenings. A complex appraisal of both clinical and statistical test results went into the WADC evaluation of candidates. As in the case of the Lovelace examinations, results were not a matter of passing or failing, but instead were measures of how one candidate compared with all others.

3. *Final selection.*—Data from the Lovelace and WADC examinations were compiled and forwarded to the NASA Langley space flight activity, for the fourth and final step in the selection process. At Langley, a group representing both the medical and technical fields evaluated the previous examinations. The seven ultimately selected were chosen as a result of physical, psychological and stress tolerance abilities and because of the technical experience each represents.

Clinical examinations given by the Lovelace Clinic

Medical history and physical examination, with internal examinations and orthopedic or other specialty consultations, included:

1. Laboratory tests: hemoglobin (measure of oxygen carrying red pigment); hematocrit (examination of blood by use of a centrifuge); grouping; Rh factor; serology (examination of blood serums); sedimentation rate (analysis of urine deposits); stool examinations; urinalysis; gastric analysis; cholesterol (substance present in gallstones, heart ailments, etc.); liver function test; urinary steroid excretion (measures of the hormones, acids and poisons); blood nitrogen; blood protein; protein-bound iodine; special serum studies; throat culture, and chemical examination of body outputs, and blood counts.

2. X-rays: chest, large intestine, sinuses, spine, stomach, esophagus, teeth and heart. Moving pictures were taken of the heart to determine any artery calcification.

3. Eyes: history, dilation, visual fields, tonometry (measure of inner pressure on the eyes), slit lamp, dynamic visual acuity, depth perception, night vision, and photography of conjunctival vessel (eye membrane) and retina.

4. Ears, nose, and throat: examination of throat and nasal passages; audiogram with and without background noises; speech discrimination and voice tape recording.

5. Heart: cardiograms of heart muscle contraction, heart stroke volume and heart sounds; measure of the chest which overlies the heart.

6. Nerves and muscles: general neurologic examination with muscle testing; electric stimulation of the nerves to determine response; measure of any nerve abnormality; tracing of electric currents produced by the brain.

Special dynamic examinations given by the Lovelace Clinic to measure body efficiency:

1. Physical competence: measured by an ergometer, a device similar to a bicycle. Subject pedals increasing amount of weight while wearing an oxygen mask. Heartbeat and oxygen consumption determined. Evaluation is made by the amount subject can pedal by the time his heart reaches 180 beats per minute.

2. Pulmonary function: lung capacity and breathing efficiency determined by measuring the amount of oxygen subject breathes normally and during exercise.

3. Lean body mass: a correlation of the following:

Total body radiation count, conducted by the Atomic Energy Commission's Los Alamos Laboratories to determine the amount of potassium in the body.

Specific gravity, weighing the subject in air and while he is totally immersed in water.

Blood volume, measured by inhaling a small amount of carbon monoxide and observing the amount absorbed by the blood after a specified time.

Water volume, determined by swallowing a small amount of tritium and observing its rate of dilution.

4. Presence of heart-chamber openings: amount of blood oxygen is measured during and after a Valsalva maneuver. The Valsalva exercise is accomplished by blocking the nose and blowing into a tube.

Stress tests conducted at the Wright Air Development Center

1. Harvard step: subject steps up 20 inches to a platform and down once every 2 seconds for 5 minutes to measure his physical fitness.
2. Treadmill maximum workload: Subject walks at a constant rate on a moving platform which is elevated 1 degree each minute. Test continues until heart reaches 180 beats per minute. Test of physical fitness.
3. Cold pressor: Subject plunges his feet into a tub of ice water. Pulse and blood pressure measured before and during test.
4. Complex behavior simulator: A panel with 12 signals, each requiring a different response. Measure of ability to react reliably under confusing situations.
5. Tilt table: Subject lays on steeply inclined table for 25 minutes to measure ability of the heart to compensate for body in an unusual position for an extended time.
6. Partial pressure suit: Subject is taken in pressure chamber to a simulated altitude of 65,000 feet in an MC1 partial pressure suit. Test lasts 1 hour. Measure of efficiency of heart system and breathing at low ambient pressures.
7. Isolation: Subject goes into a dark, soundproof room for 3 hours to determine his ability to adapt to unusual circumstances and to cope with the absence of external stimuli.
8. Acceleration: Subject is placed in a centrifuge with his seat inclined at various angles to measure his ability to withstand multiple gravity forces.
9. Heat: Subject spends 2 hours in a chamber with the temperature at 130° F. to measure reaction of heart and body functions while under this stress.
10. Equilibrium and vibration: Subject is seated on a chair which rotates simultaneously on two axes. He is required to maintain the chair on an even keel by means of a control stick with and without vibration, normally and while blindfolded.
11. Noise: Subject is exposed to a variety of sound frequencies to determine his susceptibility to tones of high frequency.

Psychological tests administered at the Wright Air Development Center

1. To determine personality and motivation: Interviews; Rorschach (ink blot); apperception (tell stories suggested by pictures); draw-a-person; sentence completion; self-inventory based on 566-item questionnaire; officer effectiveness inventory; personal preference schedule

based on 225 pairs of self-descriptive statements; personal inventory based on 20 pairs of self-descriptive statements; preference evaluation based on 52 statements; determination of authoritorian attitudes, and interpretation of the question, Who am I?

2. To determine intelligence and special aptitudes: Wechsler adult scale; Miller analogies; Raven matrices; Doppelt mathematical reasoning test; engineering analogies; mechanical comprehension; officer qualification test; aviation qualification test; space memory; spatial orientation; hidden figures perception; spatial visualization, and peer ratings.

Members of NASA Life Sciences Committee

Chairman, Dr. W. Randolph Lovelace II, Director of the Lovelace Foundation for Medical Education and Research, Albuquerque, N. Mex. Members: Capt. Norman L. Barr (MC), Director, Astronautical Division, Navy Bureau of Medicine and Surgery, Washington, D.C.; Lt. Comdr. John H. Ebersole (MC), medical officer, U.S.S. *Seawolf*, Fleet Post Office, New York, N.Y.; Brig. Gen. Don D. Flickinger (MC), Staff Surgeon and Director of Life Sciences, Headquarters, Air Research and Development Command, Washington, D.C.; Lt. Col. Robert H. Holmes (MC), Chief of Biophysics and Astronautics Branch, Army Medical Research and Development Command, Washington, D.C.; Dr. Wright H. Langham, Los Alamos Scientific Laboratory, University of California; Dr. Robert B. Livingston, Director of Basic Research in Mental Health and Neurological Diseases, National Institutes of Health, Bethesda, Md.; and Dr. Orr Reynolds, Director of Science, Office of the Assistant Secretary of Defense for Research and Engineering, Washington, D.C. Boyd C. Myers II, NASA headquarters, is secretary of the Committee.

PART V. PROJECT MERCURY ASTRONAUTS

1. SELECTION OF MERCURY ASTRONAUTS

Seven astronauts reported to the space flight activity at the NASA Langley Research Center, Hampton, Va., in April 1949 for Project Mercury orbital flight training. The seven volunteers selected were chosen to provide a variety of technical experience for the project in addition to training as astronauts.

Initial plans called for 12 men to undergo astronaut training. During the selection process, it became apparent that the Mercury team would consist of pilots adapted to the demands of the manned satellite program, and a reevaluation of Mercury requirements indicated a smaller number was desirable.

Because many of the unusual conditions expected in space flight are similar to those experienced by military test pilots, NASA went to this field for volunteers for the astronaut program. The general requirements were: possession of a bachelor's degree or equivalent in engineering or the physical sciences; graduation from a military test pilot school; 1,500 hours of jet flying time; under age 40; and 5 feet 11 inches in height or less. The educational requirement was set because of the variety of scientific and technical problems that would confront the astronauts throughout the program.

A preliminary screening of records indicated that more than 100 active graduates of military test pilot schools would qualify under these requirements. It was found unnecessary to contact all of them, because of the first 69 called to Washington to hear the Mercury project outlined, 80 percent volunteered. All were of such high caliber that selection was difficult. Through individual interviews and suitability discussions to determine motivation, experience and technical background, a group of 32 was selected to proceed further in the program. The 7 Mercury astronauts finally selected come from this group of 32.

From Washington, the selection schedule took the pilots first to Lovelace Clinic in Albuquerque, N. Mex., and then to the Wright Air Development Center Aeromedical Laboratories, Wright-Patterson Air Force Base, Ohio. At Lovelace, candidates were given exacting physical examinations. At WADC, the Air Force, with the assistance of Army and Navy specialists, assessed candidates in the psychological and stress tolerance areas. The selection process ended at the NASA Langley space flight activity, where final evaluation was undertaken by a group representing both medical and scientific professions.

The astronauts will train at a number of locations throughout the country, including the Wright Air Development Center; Naval Air Development Center, Johnsville, Pa.; Atlantic Missile Range, Cape Canaveral, Fla., and at biomedical centers throughout the country. The home of the astronauts, and the location of the NASA Space Task Group, is at the NASA Langley space flight facility.

2. MERCURY ASTRONAUT TRAINING PROGRAM

The initial phase of the astronaut training program is broken down into six areas of activity:

1. *Education in the basic sciences.*—Essentially an academic educational program, this area includes instruction in astronautics, particularly ballistics, trajectories, fuels, guidance, and other aspects of missile operations, basic aviation medicine and orbital flight hygiene, the space environment, astronomy, meteorology, astrophysics, and geography, including the techniques for making scientific observations in these areas.

2. *Familiarization with the conditions of space flight.*—This phase of training is designed to familiarize the astronauts with the heat, pressure, G force levels and other special conditions of space flight. It includes periodic simulated flights in centrifuges and pressure chambers, weightless flying, training in human disorientation devices, the development of techniques to minimize the effects of vertigo, and experiments with high heat environments.

This part of the training program will provide data on the ability of the astronaut to contribute to system reliability under the conditions to be encountered during flight, the psychological and physiological effects of the normal and various emergency conditions which may be encountered during flight, and the requirements for the support and restraint systems, the environmental control system, and the crew space layout.

3. *Training in the operation of the Mercury space vehicle.*—The objective of this segment of the program is to provide a thorough knowledge in the operation and maintenance of the Mercury vehicle and its component subsystems, with particular emphasis being placed on the use and maintenance of the scientific instruments and life-support equipment.

4. *Participation in the vehicle development program.*—Each of the astronauts is assigned to a system or subsystem of the Mercury vehicle. In this work, he will acquire specialized knowledge of value to the entire group. This information is exchanged in a series of informal seminars.

Actual work on the vehicle development program by the astronauts will provide limited augmentation of the Space Task Group staff as well as providing them with an intimate knowledge of all aspects of the Mercury vehicle itself.

5. *Aviation flight training.*—The Mercury astronauts will continue to maintain their proficiency in high performance aircraft in an aviation flight training program. Continued operation of high performance aircraft will give them additional altitude acclimatization, instrument flight training and the physiology of high altitude, high speed flight.

6. *Integration of astronaut and ground support and launch crew operation.*—Familiarization with the operation of ground support equipment and launch crew operations will be accomplished in coordination with the agencies providing boosters and launch facilities. Training in the operation and use of ground support equipment and observation of launch operations will provide the astronauts with complete knowledge of the launch phase of Mercury flights.

Existing research, development, training and test facilities of the armed services, industry and educational institutions throughout the country will be utilized for maximum effectiveness at minimum cost. A number of experts in many of the scientific and technical subject areas will give lectures to the astronauts during their educational program.

The concentrated astronaut education program began with overall program orientation briefings by members of the Space Task Group staff. While assigned to the Langley facility, the Mercury astronauts will work as integrated members of the NASA Space Task Group.

Each of the Mercury astronauts has been detailed to the NASA by his respective military service but is still considered to be on active duty and is receiving military service pay. The astronauts will remain on duty with NASA on a full-time basis.

Completed training activities

1. Visit to McDonnell Aircraft Corp., St. Louis, for capsule familiarization.
2. Wright Air Development Center:
   (*a*) General pressure suit indoctrination:
      (1) Centrifuge ride using Redstone and Atlas launch profiles.
      (2) Reentry heat profile with suits unpressurized but vented.
      (3) Pressure chamber run to 100,000 feet with suit pressurized.
   (*b*) Check of low residue diets for 3 days.
3. Naval Medical Research Institute of Bethesda, Md.:
   (*a*) Determination of basal metabolic rate, cutaneous blood flow rate, and sweat rate at environmental temperatures of 95° F. and 114° F.
   (*b*) Familiarization with the effects of excessive carbon dioxide.
4. Visit to Cape Canaveral:
   (*a*) Familiarization with the organization of the Ballistic Missile Division and the Atlantic Missile Range.
   (*b*) Study of launching procedures and missiles under development at Cape Canaveral.
5. Witness of capsule recovery operation on board a naval destroyer.
   (*a*) This recovery took place at sea when the capsule was dropped from a C–130 airplane from an altitude of 20,000 feet.
6. Skin diving training at Navy Little Creek Amphibious Base.
   (*a*) To simulate the effects of the weightless state and maintain physical fitness of the astronauts.
7. Visit to Army Ballistic Missile Agency.
   (*a*) This trip was to familiarize the astronauts with the Redstone Missile.
8. Acceleration studies with centrifuge at Johnsville.
9. Trip to Convair, San Diego, for familiarization with the Atlas booster.
   (*a*) Tour of plant facilities.
   (*b*) Study of Atlas construction and operational procedures.
   (*c*) Discussions with Convair engineers.
10. Trip to Edwards Air Force Base for briefing on the X–15 research airplane.
11. Fittings for pressure suits at contractor's (Goodrich) plant.

Future and continuing training activities

1. Study of space mechanics and sciences: This study consists of discussion-type training sessions led by NASA engineers and scientists. Six to ten hours of almost every week have been spent on these subjects.
2. Pressure suit checks in the McDonnell capsule at St. Louis.
3. Speciality work area assignments.
4. Training on NASA space flight simulator to develop physical skills in retrofiring and reentry.
5. Continuation of studies in space mechanics and sciences.
6. Continual participation in the vehicle development program.
7. Continuation of flight and simulator training.
8. Participation in research and development launch and recovery activities.
9. Periodic visits to McDonnell for checkout procedures and training.
10. Survival, disorientation, and communications training at Pensacola, Fla.
11. Flights for practice in eating and drinking in the weightless state.

Astronaut specialty area assignments

1. Malcolm S. Carpenter: Communications and navigational aids.
2. Leroy G. Cooper: Redstone booster.
3. John H. Glenn: Crew space layout.
4. Virgil I. Grissom: Automatic and manual attitude control system.
5. Walter M. Schirra: Life support system.
6. Alan B. Shepard: Range, tracking, and recovery operations.
7. Donald K. Slayton: The Atlas booster.

3. NASA POLICY CONCERNING MERCURY ASTRONAUTS

The Mercury astronauts have been detailed to NASA by their respective military departments pursuant to an agreement approved by the President which makes them subject to the regulations and directives of NASA in the performance of their duties.

It is recognized that the experiences of the Mercury astronauts through all phases of Project Mercury, from the commencement of training to accomplishment of orbital flight, will be of great interest to the public. NASA has therefore adopted the following policy on disclosure of information concerning the experiences of the Mercury astronauts:

1. All information reported by the Mercury astronauts in the course of their official duties which is not classified to protect the national security will be promptly made available to the public by NASA.
2. Public information media will be granted frequent accessibility to the Mercury astronauts for the purpose of obtaining information from them concerning their activities in Project Mercury. The timing and conditions of interviews with the Mercury astronauts for this purpose will be controlled by the NASA Director of Public Information so as not to interfere with their performance of official duties. During such interviews, the Mercury astronauts will be directed to disclose all information acquired in the course of their activities in

Project Mercury, except information classified to protect the national security.

3. While detailed to NASA for duties in connection with Project Mercury, the Mercury astronauts—

(*a*) may not, without the prior approval of the NASA Director of Public Information, appear on television or radio programs or in motion pictures;

(*b*) may not, without the prior approval of the NASA Director of Public Information, publish, or collaborate in the publication of, writings of any kind;

(*c*) may not receive compensation in any form for radio, television, or motion picture appearances, or for the publication of writings of any kind, which involve reporting to the public their performance of official duties in any phase of Project Mercury; and

(*d*) may not endorse commercial products.

4. The Mercury astronauts are free, singly and collectively, to make any agreement they see fit for the sale of their personal stories, including rights in literary work, motion pictures, radio and television productions, provided such agreements do not violate the foregoing restrictions. (The astronauts collectively have made such a contract with Life magazine for a reported sum of one-half million dollars.)

APPENDIXES

APPENDIX A

General References to Space Flight

1. INTRODUCTION TO OUTER SPACE

(A Statement by the President, and Introduction to Outer Space—An Explanatory Statement Prepared by the President's Science Advisory Committee)

The White House, March 26, 1958

Statement by the President

In connection with a study of space science and technology made at my request, the President's Science Advisory Committee, of which Dr. James R. Killian is Chairman, has prepared a brief "Introduction to Outer Space" for the nontechnical reader.

This is not science fiction. This is a sober, realistic presentation prepared by leading scientists.

I have found this statement so informative and interesting that I wish to share it with all the people of America and indeed with all the people of the earth. I hope that it can be widely disseminated by all news media for it clarifies many aspects of space and space technology in a way which can be helpful to all people as the United States proceeds with its peaceful program in space science and exploration. Every person has the opportunity to share through understanding in the adventures which lie ahead.

This statement of the Science Advisory Committee makes clear the opportunities which a developing space technology can provide to extend man's knowledge of the earth, the solar system, and the universe. These opportunities reinforce my conviction that we and other nations have a great responsibility to promote the peaceful use of space and to utilize the new knowledge obtainable from space science and technology for the benefit of all mankind.

Dwight D. Eisenhower.

Introduction to Outer Space—An Explanatory Statement Prepared by the President's Science Advisory Committee

What are the principal reasons for undertaking a national space program? What can we expect to gain from space science and exploration? What are the scientific laws and facts and the technological means which it would be helpful to know and understand in reaching sound policy decisions for a United States space program and its management by the Federal Government? This statement seeks to provide brief and introductory answers to these questions.

It is useful to distinguish among four factors which give importance, urgency, and inevitability to the advancement of space technology.

The first of these factors is the compelling urge of man to explore and to discover, the thrust of curiosity that leads men to try to go where no one has gone before. Most of the surface of the earth has now been explored and men now turn to the exploration of outer space as their next objective.

Second, there is the defense objective for the development of space technology. We wish to be sure that space is not used to endanger our security. If space is to be used for military purposes, we must be prepared to use space to defend ourselves.

Third, there is the factor of national prestige. To be strong and bold in space technology will enhance the prestige of the United States among the peoples of the world and create added confidence in our scientific, technological, industrial, and military strength.

Fourth, space technology affords new opportunities for scientific observation and experiment which will add to our knowledge and understanding of the earth, the solar system, and the universe.

The determination of what our space program should be must take into consideration all four of these objectives. While this statement deals mainly with the use of space for scientific inquiry, we fully recognize the importance of the other three objectives.

In fact it has been the military quest for ultra long-range rockets that has provided man with new machinery so powerful that it can readily put satellites in orbit, and, before long, send instruments out to explore the moon and nearby planets. In this way, what was at first a purely military enterprise has opened up an exciting era of exploration that few men, even a decade ago, dreamed would come in this century.

WHY SATELLITES STAY UP

The basic laws governing satellites and space flight are fascinating in their own right. And while they have been well known to scientists even since Newton, they may still seem a little puzzling and unreal to many of us. Our children, however, will understand them quite well.

We all know that the harder you throw a stone the farther it will travel before falling to earth. If you could imagine your strength so fantastically multiplied that you could throw a stone at a speed of 15,000 m.p.h., it would travel a great distance. It would, in fact, easily cross the Atlantic Ocean before the earth's gravity pulled it down. Now imagine being able to throw the stone just a little faster, say about 18,000 m.p.h., what would happen then?

The stone would again cross the ocean, but this time it would travel much farther than it did before. It would travel so far that it would overshoot the earth, so to speak, and keep falling until it was back where it started. Since in this imaginary example there is no atmospheric resistance to slow the stone down, it would still be travelling at the original speed, 18,000 m.p.h., when it had got back to its starting point. So around the earth it goes again. From the stone's point of view, it is continuously falling, except that its very slight downward arc exactly matches the curvature of the earth, and so it stays aloft—or as the scientist would say, "in orbit"—indefinitely.

Since the earth has an atmosphere, of course, neither stones nor satellites can be sent whizzing around the earth at tree-top level. Satellites must first be lifted beyond the reach of atmospheric resistance. It is absence of atmospheric resistance plus speed that makes the satellite possible. It may seem odd that weight or mass has nothing to do with a satellite's orbit. If a feather were released from a 10-ton satellite, the two would stay together, following the same path in the airless void. There is, however, a slight vestige of atmosphere even a few hundred miles above the earth, and its resistance will cause the feather to spiral inward toward the earth sooner than the satellite. It is atmospheric resistance, however slight, that has set limits on the life of all satellites launched to date. Beyond a few hundred miles the remaining trace of atmosphere fades away so rapidly that tomorrow's satellites should stay aloft thousands of years, and, perhaps, indefinitely. The higher the satellite, incidentally, the less speed it needs to stay in orbit once it gets there (thus, the moon's speed is only a little more than 2,000 m.p.h.), but to launch a satellite toward a more distant orbit requires a higher initial speed and greater expenditure of energy.

THE THRUST INTO SPACE

Rocket engineers rate rockets not in horsepower, but in thrust. Thrust is just another name for push, and it is expressed in pounds of force. The rocket gets its thrust or push by exhausting material backward. It is this thrust that lifts the rocket off the earth and accelerates it, making it move faster and faster.

As everyone knows, it is more difficult to accelerate an automobile than a baby carriage. To place satellites weighing 1,000 to 2,000 pounds in orbit requires a first-stage rocket, engine, or engines, having a thrust in the neighborhood of 200,000 to 400,000 pounds. Rocket engines able to supply this thrust have been under development for some time. For launching a satellite, or other space vehicle, the rocket engineer divides his rockets into two, three, or more stages, which can be dropped one after the other in flight, thus reducing the total weight that must be accelerated to the final velocity desired. (In other words, it is a great waste of energy to lift one huge fuel tank into orbit when the tank can be divided into smaller tanks—each packaged in its own stage with its own rocket motor—that can be left behind as they become empty.)

To launch some of the present satellites has required rockets weighing up to 1,000 times the weight of the satellite itself. But it will be possible to reduce takeoff weights until they are only 50 to 100 times that of the satellite. The rocket's high ratio of gross weight to payload follows from a fundamental limitation in the exhaust velocities that can be achieved by chemical propellants.

If we want to send up not a satellite but a device that will reach the moon, we need a larger rocket relative to its payload in order that the final stage can be accelerated to about 25,000 m.p.h. This speed, called the "escape velocity," is the speed with which a projectile must be thrown to escape altogether from the gravitational pull of the earth. If a rocket fired at the moon is to use as little fuel as possible, it must attain the escape velocity very near the beginning of its trip. After this peak speed is reached, the rocket will be gradually slowed down by the earth's pull, but it will still move fast enough to reach the moon in 2 or 3 days.

THE MOON AS A GOAL

Moon exploration will involve three distinct levels of difficulty. The first would be a simple shot at the moon, ending either in a "hard" landing or a circling of the moon. Next in difficulty would be a "soft" landing. And most difficult of all would be a "soft" landing followed by a safe return to earth.

The payload for a simple moon shot might be a small instrument carrier similar to a satellite. For the more difficult "soft" landing, the carrier would have to include, as part of its payload, a "retro-rocket" (a *de*celerating rocket) to provide braking action. since the moon has no atmosphere that could serve as a cushion.

To carry out the most difficult feat, a round trip to the moon, will require that the initial payload include not only "retro-rockets" but rockets to take off again from the moon. Equipment will also be required aboard to get the payload through the atmosphere and safely back to earth. To land a man on the moon and get him home safely again will require a very big rocket engine indeed—one with a thrust in the neighborhood of one or two million pounds. While nuclear power may prove superior to chemical fuels in engines of multi-million-pound thrust, even the atom will provide no short cut to space exploration.

Sending a small instrument carrier to Mars, although not requiring much more initial propulsion than a simple moon shot, would take a much longer travel time (8 months or more). and the problems of navigation and final guidance are formidable.

A MESSAGE FROM MARS

Fortunately, the exploration of the moon and nearby planets need not be held up for lack of rocket engines big enough to send men and instrument carriers out into space and home again. Much that scientists wish to learn from satellites and space voyages into the solar system can be gathered by instruments and transmitted back to earth. This transmission, it turns out, is relatively easy with today's rugged and tiny electronic equipment.

For example, a transmitter with a power of just one or two watts can easily radio information from the moon to the earth. And messages from Mars, on the average some 50 million to 100 million miles away at the time the rocket would arrive, can be transmitted to earth with less power than that used by most commercial broadcasting stations. In some ways, indeed, it appears that it will be easier to send a clear radio message between Mars and earth than between New York and Tokyo

This all leads up to an important point about space exploration. The cost of transporting men and material through space will be extremely high, but the cost and difficulty of sending *information* through space will be comparatively low.

WILL THE RESULTS JUSTIFY THE COSTS?

Since the rocket power plants for space exploration are already in existence or being developed for military need, the cost of additional scientific research, using these rockets, need not be exorbitant. Still, the cost will not be small, either. This raises an important question that scientists and the general public (which will pay the bill) both must face: Since there are still so many unanswered scientific questions and problems all around us on earth, why should we start asking new questions and seeking out new problems in space? How can the results possibly justify the cost?

Scientific research, of course, has never been amenable to rigorous cost accounting in advance. Nor, for that matter, has exploration of any sort. But if we have learned one lesson, it is that research and exploration have a remarkable way of paying off—quite apart from the fact that they demonstrate that man is alive and insatiably curious. And we all feel richer for knowing what explorers and scientists have learned about the universe in which we live.

It is in these terms that we must measure the value of launching satellites and sending rockets into space. These ventures may have practical utility some of which will be noted later. But the scientific questions come first.

THE VIEW FROM A SATELLITE

Here are some of the things that scientists say can be done with the new satellites and other space mechanisms. A satellite in orbit can do three things: (1) It can sample the strange new environment through which it moves; (2) it can look down and see the earth as it has never been seen before; and (3) it can look out into the universe and record information that can never reach the earth's surface because of the intervening atmosphere.

The satellite's immediate environment at the edge of space is empty only by earthly standards. Actually "empty" space is rich in energy, radiation, and fast-moving particles of great variety. Here we will be exploring the active medium, a kind of electrified plasma, dominated by the sun, through which our earth moves. Scientists have indirect evidence that there are vast systems of magnetic fields and electric currents that are connected somehow with the outward flow of charged material from the sun. These fields and currents the satellites will be able to measure for the first time. Also for the first time, the satellites will give us a detailed three-dimensional picture of the earth's gravity and its magnetic field.

Physicists are anxious to run one crucial and fairly simple gravity experiment as soon as possible. This experiment will test an important prediction made by Einstein's General Theory of Relativity; namely, that a clock will run faster as the gravitational field around it is reduced. If one of the fantastically accurate clocks, using atomic frequencies, were placed in a satellite and should run faster than its counterpart on earth, another of Einstein's great and daring predictions would be confirmed. (This is not the same as the prediction that any moving clock will appear to a stationary observer to lose time—a prediction that physicists already regard as well confirmed.)

There are also some special questions about cosmic rays which can be settled only by detecting the rays before they shatter themselves against the earth's atmosphere. And, of course, animals carried in satellites will begin to answer the question: What is the effect of weightlessness on physiological and psychological functions? (Gravity is not felt inside a satellite because the earth's pull is precisely balanced by centrifugal force. This is just another way of saying that bodies inside a satellite behave exactly as they would inside a freely falling elevator.)

The satellite that will turn its attention downward holds great promise for meteorology and the eventual improvement of weather forecasting. Present weather stations on land and sea can keep only about 10 percent of the atmosphere under surveillance. Two or three weather satellites could make a cloud inventory of the whole globe every few hours. From this inventory meteorologists believe they could spot large storms (including hurricanes) in their early stages and chart their direction of movement with much more accuracy than at present. Other instruments in the satellites will measure for the first time how much solar energy is falling upon the earth's atmosphere and how much is reflected and radiated back into space by clouds, oceans, the continents, and by the great polar ice fields.

It is not generally appreciated that the earth has to send back into space, over the long run, exactly as much heat energy as it receives from the sun. If this were not so the earth would either heat up or cool off. But there is an excess of income over outgo in the tropical regions, and an excess of outgo over income in the polar regions. This imbalance has to be continuously rectified by the activity of the earth's atmosphere which we call weather.

By looking at the atmosphere from the outside, satellites will provide the first real accounting of the energy imbalances, and their consequent tensions, all around the globe. With the insight gained from such studies, meteorologists hope they may improve long-range forecasting of world weather trends.

Finally, there are the satellites that will look not just around or down, but out into space. Carrying ordinary telescopes as well as special instruments for recording X-rays, ultraviolet, and other radiations, these satellites cannot fail to reveal new sights forever hidden from observers who are bound to the earth. What these sights will be, no one can tell. But scientists know that a large part of all stellar radiation lies in the ultraviolet region of the spectrum, and this is totally blocked by the earth's atmosphere. Also blocked are other very long wavelengths of "light" of the kind usually referred to as radio waves. Some of these get through the so-called "radio window" in the atmosphere and can be detected by radio telescopes, but scientists would like a look at the still longer waves that cannot penetrate to earth.

Even those light signals that now reach the earth can be recorded with brilliant new clarity by satellite telescopes. All existing photographs of the moon and nearby planets are smeared by the same turbulence of the atmosphere that makes the stars twinkle. Up above the atmosphere the twinkling will stop and we should be able to see for the first time what Mars really looks like. And we shall want a really sharp view before launching the first rocket to Mars.

A CLOSE-UP OF THE MOON

While these satellite observations are in progress, other rockets will be striking out for the moon with other kinds of instruments. Photographs of the back or hidden side of the moon may prove quite unexciting, or they may reveal some spectacular new feature now unguessed. Of greater scientific interest is the question whether or not the moon has a magnetic field. Since no one knows for sure why the earth has such a field, the presence or absence of one on the moon should throw some light on the mystery.

But what scientists would most like to learn from a close-up study of the moon is something of its origin and history. Was it originally molten? Does it now have a fluid core, similar to the earth's? And just what is the nature of the lunar surface? The answer to these and many other questions should shed light, directly or indirectly, on the origin and history of the earth and the surrounding solar system.

While the moon is believed to be devoid of life, even the simplest and most primitive, this cannot be taken for granted. Some scientists have suggested that small particles with the properties of life—germs or spores—could exist in space and could have drifted on to the moon. If we are to test this intriguing hypothesis we must be careful not to contaminate the moon's surface, in the biological sense, beforehand. There are strong scientific reasons, too, for avoiding radioactive contamination of the moon until its naturally acquired radioactivity can be measured.

. . . AND ON TO MARS

The nearest planets to earth are Mars and Venus. We know quite enough about Mars to suspect that it may support some form of life. To land instrument carriers on Mars and Venus will be easier, in one respect, than achieving a "soft" landing on the moon. The reason is that both planets have atmospheres that can be used to cushion the final approach. These atmospheres might also be used to support balloons equipped to carry out both meteorological soundings and a general photo survey of surface features. The Venusian atmosphere, of course, consists of what appears to be a dense layer of clouds so that its surface has never been seen at all from earth.

Remotely controlled scientific expeditions to the moon and nearby planets could absorb the energies of scientists for many decades. Since man is such an adventurous creature, there will undoubtedly come a time when he can no longer resist going out and seeing for himself. It would be foolish to try to predict today just when this moment will arrive. It might not arrive in this century, or it might come within one or two decades. So much will depend on how rapidly we want to expand and accelerate our program. According to one rough estimate it might require a total investment of about a couple of billion dollars, spent over a number of years to equip ourselves to land a man on the moon and to return him safely to earth.

THE SATELLITE RADIO NETWORK

Meanwhile, back at earth, satellites will be entering into the everyday affairs of men. Not only will they be aiding the meteorologists, but they could surely—and rather quickly—be pressed into service for expanding world-wide communications, including intercontinental television.

At present all trans-oceanic communication is by cable (which is costly to install) or by shortwave radio (which is easily disrupted by solar storms). Television cannot practically be beamed more than a few hundred miles because the wavelengths needed to carry it will not bend around the earth and will not bounce off the region of the atmosphere known as the ionosphere. To solve this knotty problem, satellites may be the thing, for they can serve as high-flying radio relay stations. Several suitably equipped and properly spaced satellites would be able to receive TV signals from any point on the globe and to relay them directly—or perhaps via a second satellite—to any other point. Powered with solar batteries, these relay stations in space should be able to keep working for many years.

MILITARY APPLICATIONS OF SPACE TECHNOLOGY

The development of military rockets has provided the technological base for space exploration. It will probably continue to do so, because of the commanding military importance of the ballistic missile. The subject of ballistic missiles lies outside our present discussion. We ask instead, putting missiles aside, what other military applications of space technology can we see ahead?

There are important, foreseeable, military uses for space vehicles. These lie, broadly speaking, in the fields of *communication* and *reconnaissance*. To this we could add meteorology, for the possible advances in meteorological science which have already been described would have military implications. The use of satellites for radio relay links has also been described, and it does not take much imagination to foresee uses of such techniques in long range military operations.

The reconnaissance capabilities of a satellite are due, of course, to its position high above the earth and the fact that its orbit carries it in a predictable way over much of the globe. Its disadvantage is its necessarily great distance, 200 miles or more, from the surface. A highly magnifying camera or telescope is needed to picture the earth's surface in even moderate detail. To the human eye, from 200 miles away, a football stadium would be a barely distinguishable speck. A telescopic camera can do a good deal better, depending on its size and complexity. It is certainly feasible to obtain reconnaissance information with a fairly elaborate instrument, information which could be relayed back to the earth by radio.

Much has been written about space as a future theater of war, raising such suggestions as satellite bombers, military bases on the moon, and so on. For the most part, even the more sober proposals do not hold up well on close examination or appear to be achievable at an early date. Granted that they will become technologically possible, most of these schemes, nevertheless, appear to be clumsy and ineffective ways of doing a job. Take one example, the satellite as a bomb carrier. A satellite cannot simply drop a bomb. An object released from a satellite doesn't fall. So there is no special advantage in being over the target. Indeed, the only way to "drop" a bomb directly down from a satellite is to carry out aboard the satellite a rocket launching of the magnitude required for an intercontinental missile. A better scheme is to give the weapon to be launched from the satellite a small push, after which it will spiral in gradually. But that means launching it from a moving platform halfway around the world, with every disadvantage compared to a missile base on the ground. In short, the earth would appear to be, after all, the best weapons carrier.

This is only one example; each idea has to be judged on its own merits. There may well be important military applications for space vehicles which we cannot now foresee, and developments in space technology which open up quite novel possibilities. The history of science and technology reminds us sharply of the limitations of our vision. Our road to future strength is the achievement of scientific insight and technical skill by vigorous participation in these new explorations. In this setting, our appropriate military strength will grow naturally and surely.

A SPACE TIMETABLE

Thus we see that satellites and space vehicles can carry out a great variety of scientific missions, and a number of military ones as well.

Indeed, the scientific opportunities are so numerous and so inviting that scientists from many countries will certainly want to participate. Perhaps the International Geophysical Year will suggest a model for the international exploration of space in the years and decades to come.

The timetable on the following page suggests the approximate order in which some of the scientific and technical objectives mentioned in this review may be attained.

The timetable is not broken down into years, since there is yet too much uncertainty about the scale of the effort that will be made. The timetable simply lists various types of space investigations and goals under three broad headings: Early, Later. Still Later.

SCIENTIFIC OBJECTIVES

Early

1. Physics
2. Geophysics
3. Meteorology
4. Minimal Moon Contact
5. Experimental Communications
6. Space Physiology

Later

1. Astronomy
2. Extensive Communications
3. Biology
4. Scientific Lunar Investigation
5. Minimal Planetary Contact
6. Human Flight in Orbit

Still Later

1. Automated Lunar Exploration
2. Automated Planetary Exploration
3. Human Lunar Exploration and Return

And Much Later Still

Human Planetary Exploration

In conclusion, we venture two observations. Research in outer space affords new opportunities in science, but it does not diminish the importance of science on earth. Many of the secrets of the universe will be fathomed in laboratories on earth, and the progress of our science and technology and the welfare of the Nation require that our regular scientific programs go forward without loss of pace, in fact at an increased pace. It would not be in the national interest to exploit space science at the cost of weakening our efforts in other scientific endeavors. This need not happen if we plan our national program for space science and technology as part of a balanced national effort in all science and technology.

Our second observation is prompted by technical considerations. For the present, the rocketry and other equipment used in space technology must usually be employed at the very limit of its capacity. This means that failures of equipment and uncertainties of schedule are to be expected. It therefore appears wise to be cautious and modest in our predictions and pronouncements about future space activities—and quietly bold in our execution.

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Dr. Jerrold R. Zacharias, Professor of Physics, Massachusetts Institute of Technology

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2. National Academy of Sciences Establishes Space Science Board

[Press release of Aug. 3, 1958, from the National Academy of Sciences-National Research Council]

WASHINGTON, D.C., August 2.—Dr. Detlev W. Bronk, president of the National Academy of Sciences-National Research Council, announced today the formation of a 16-man Space Science Board, "to survey in concert the scientific problems, opportunities and implications of man's advance into space."

Dr. Lloyd V. Berkner, president of Associated Universities, Inc., president of the International Council of Scientific Unions and a member of the National Academy of Sciences, has been named chairman.

The Board, besides acting as the focal point for all Academy-Research Council activities connected with space-science research, will be called upon to coordinate its work with appropriate civilian and Government agencies, particularly the National Aeronautics and Space Administration, the National Science Foundation, and the Advanced Research Projects Agency, and with foreign groups active in this field.

In making the announcement, Dr. Bronk stated, "We feel that the formation of this Board can have especial significance for science as we face the challenge and adventure of the new steps into space that are surely and swiftly on the way. It is my hope that the Board will give fullest possible attention to every aspect of space science, including both the physical and the life sciences. I believe that the Academy-Research Council has a unique opportunity to bring together scientists from many fields to find ways to further a wise and vigorous national scientific program in this field."

The functions of the Board will include studies of scientific-research opportunities and needs opened up by the advent of modern rocket and satellite tools, advice and recommendations on space science to interested agencies and institutions, stimulation of research interest in the rocket and satellite fields, and cooperative activities in this area with academies and similar institutions abroad.

Eleven ad hoc committees have already been organized to carry on the work of the Board under Dr. Berkner's leadership. These committees, together with their chairmen and vice chairmen (who comprise the membership of the Board), follow:

1. Geochemistry of Space and Exploration of Moon and Planets: Chairman, Dr. Harold C. Urey, professor of chemistry, University of California, La Jolla; vice chairman, Dr. Harrison S. Brown, professor of geochemistry, California Institute of Technology.

2. Astronomy and Radio Astronomy: Chairman, Dr. Leo Goldberg, chairman, Department of Astronomy, University of Michigan.

3. Future Vehicular Development (beyond vehicles immediately available and including possible space stations and interplanetary vehicles for scientific research): Chairman, Dr. Donald F. Hornig, professor of chemistry, Princeton University.

4. International Relations Field (coordination with International Council of Scientific Unions and other national scientific bodies on problems in international sharing of payloads, international cooperation in space activities and advice on the formulation and effects of regulatory policies): Chairman, Dr. W. A. Noyes, dean, College of Arts and Science, University of Rochester.

5. Immediate Problems (space laboratories, orbits, currently feasible research projects, and liaison with the technical panel on the earth satellite program of the U.S. National Committee for the International Geophysical Year during terminal phases of IGY): Chairman, Dr. R. W. Porter, chairman of the USNC-IGY Technical Panel on the Earth Satellite Program, and consultant—communication and control, engineering services, General Electric Co., New York.

6. Space projects (analysis of advanced space research proposals and long-range planning): Chairman, Dr. Bruno B. Rossi, professor of physics, Massachusetts Institute of Technology.

7. Ionosphere (experiments pertaining to auroral and ionospheric effects, including whistlers and special propagation phenomena): Chairman, Mr. A. H. Shapley, physicist, National Bureau of Standards, Boulder, Colo.

8. Physics of Fields and Particles in Space: Chairman, Dr. John A. Simpson, professor of physics, University of Chicago; vice chairman, Dr. James A. Van Allen, head, Department of Physics, State University of Iowa.

9. Future Engineering Development Beyond Available Facilities (telecommunications, telemetry, guidance, environmental conditions and advanced laboratory requirements): Chairman, Dr. O. G. Villard, Jr., professor of electrical engineering, Stanford University.

10. Meteorological Aspects of Satellites and Space Research: Chairman, Dr. Harry Wexler, director of meteorological research, U.S. Weather Bureau.

11. Psychological and Biological Research: Chairman, Dr. H. Keffer Hartline, Biophysics Section, Rockefeller Institute for Medical Research; vice chairman, Dr. S. S. Stevens, professor of psychology, Harvard University.

A twelfth committee, on geodesy, will be chaired by a Board member still to be selected.

In describing how the Board would seek to accomplish its tasks, Dr. Berkner said, "To insure the development of U.S. space science on a broad base, we shall encourage the participation of scientists from universities and private research institutions. While Government participation is essential, we feel that it would be unwise if space science were to be developed entirely within the bounds of Government activity.

"We shall also encourage broad participation from all fields of science in order to offer useful guidance to all groups engaged in space-science research, suggesting—when advisable—the integration of similar proposals and the elimination of those that are inappropriate."

Still another task before the Board would be a program to gain the further cooperation of the International Council of Scientific Unions and other international organizations in the prevention of undesirable and unnecessary contamination of Moon and planet surfaces and atmosphere with alien particles of energy and matter introduced from Earth by space vehicles.

Named as Executive Director of the new Board was Dr. Hugh Odishaw, who also serves the Academy-Research Council as Executive Director of the U.S. National Committee for the IGY. A permanent staff will be recruited to serve as a Secretariat.

Although it is a private agency, the National Academy of Sciences-National Research Council is obliged, under the terms of a congressional charter signed in 1863 by Abraham Lincoln, to advise the Government, upon request, on any matters of scientific or technical interest. A nonprofit organization of distinguished scientists from all branches of natural science, the Academy-Research Council is dedicated to the furtherance of science and its use for the general welfare.

3. Manned Space Flight and Exploration

[Excerpt from Part II: II.G. of Report of the United Nations Ad Hoc Committee on the Peaceful Uses of Outer Space, July 14, 1959]

41. Initial interest in man's role in space has been concerned with the utilization of his unique characteristics which allow him to absorb a wide variety of observations, to remember and to make decisions in a way that cannot be duplicated by machines. Such human qualities as persistance, resourcefulness and the relative reliability of the complex human system further indicate the need for man's inclusion in the development of space flight and exploration.

42. Although unmanned vehicles will have preceded man in the exploration of space, perhaps effecting landings on the moon, penetrating interplanetary space, and at least approaching the planets, the addition of man to these efforts will constitute a dramatic innovation, one which is only in part "scientific" in purpose and only in a special sense a "practical" application of space vehicles. The motivation of manned space exploration goes deeper than any scientific and other practical results. Apparent throughout man's history is a basic urge to discover and to explore, to go where no man has gone before, to go everywhere man has the means of going. As it becomes possible for man to explore outer space, he can confidently be expected to do so.

43. The first demonstrations of manned space flight can be expected in the near future, probably in the form of experiments with rockets followed by relatively simple manned orbital vehicles. Looking well beyond such initial efforts, it is possible to foresee the initiation of true manned exploration of space, that is the use of space vehicles to enable man to reach, investigate and return from the moon, interplanetary space, and ultimately at least the near planets. There does not appear to be any foreseeable prospect of manned exploration of interstellar space.

44. Although no insuperable problems have yet been identified, the scientific and technical problems of true manned space exploration are substantial, and the period required for full perfection of the necessary vehicles, equipment instrumentation and techniques will be measured in terms of decades rather than years.

APPENDIX B

Biological and Medical Aspects of Space Flight

1. Academy-Research Council, Armed Forces Join in Study of Biological Effects of Space Flight

[Press release of Feb. 9, 1959, from the National Academy of Sciences-National Research Council]

Washington, February 8.—The National Academy of Sciences-National Research Council announced today the organization of the Armed Forces-National Research Council Committee on Bio-Astronautics. The Committee will advise the Armed Forces, upon their request, in any matter concerning the biological or medical aspects of space exploration.

Policy decisions and the programing of activities within the Committee will be the responsibility of an Executive Council. The following scientists—representing different fields of endeavor in universities, private research organizations, and the Armed Forces—have been appointed to the Executive Council by Dr. Detlev W. Bronk, President of the Academy-Research Council: Chairman, Dr. Otto H. Schmitt, Department of Physics, University of Minnesota; Vice Chairman, Dr. Melvin Calvin, Department of Chemistry, University of California, Berkeley; Dr. Howard J. Curtis, Department of Biology, Brookhaven National Laboratory; Dr. Paul M. Fitts, Department of Psychology, University of Michigan; Brig. Gen. Don D. Flickinger, Directorate of Life Sciences, Air Research and Development Command; Dr. John D. French, Department of Anatomy, University of California Medical Center, Los Angeles; Capt. Charles F. Gell, Office of Naval Research; Dr. James D. Hardy, U.S. Naval Air Development Center, Johnsville, Pa.; and Col. Robert H. Holmes, Research and Development Command, Office of the Surgeon General, Department of the Army.

The full Committee on Bio-Astronautics—which will consist of more than 100 members, of whom at least half will be nominees of the Armed Forces—will serve as a conference or forum of active investigators, meeting periodically to review scientific and technical problems, exchange information, and establish liaison between investigators with allied interests.

Administrative responsibility for the Committee has been vested within the Academy-Research Council's Division of Medical Sciences, whose chairman is Dr. R. Keith Cannan. Acting executive secretary to the Committee is Dr. Sam F. Seeley; previous to his retirement after 31 years of Army service, Dr. Seeley had been Chief of the Professional Division in the Office of the Surgeon General. Both Dr. Cannan and Dr. Seeley participate in Executive Council meetings as ex-officio members. The third ex-officio member is Maj. Kay Cutler, Air Research and Development Command. Assigned to serve as assistant executive secretary has been Lt. Col. Clarence Cain, USAF, formerly Chief of the Bio-Medical Division, Directorate of Life Sciences, Air Research, and Development Command.

At a recent organizational meeting, the Executive Council agreed to the following goals:

1. Acquainting scientific investigators with the military requirements for establishing space as an operational medium for man.
2. Considering and reporting upon military problems related to manned space operations.
3. Assisting in providing scientists and military personnel with access to scientific and technical information pertaining to the bioastronautical problems of life in space.
4. Promoting the exchange of research information on bioastronautical problems through such media as meetings, symposia, and forums.
5. Stimulating research on all problems of life in space where deficiencies of knowledge warrant special effort.
6. Furthering the science of bioastronautics by encouraging the contributions of the many related fields of science.
7. Providing specific answers to specific problems posed by the Armed Forces.

The Committee will concern itself with any field of science or of technology that it finds necessary in pursuit of its objectives, including pertinent aspects of astronautics, biology, chemistry, medicine, physiology, psychology, and related interdisciplinary sciences. Specific examples are:

1. Closed-system environments
2. Stress
3. Crew selection, motivation, surveillance and control, including group dynamics
4. Ground support facilities
5. Weightlessness—physiological and psychological aspects
6. Metabolic requirements, including nutrition, water balance, electrolyte balance, etc.
7. Cosmic and other forms of radiation
8. Isolation and confinement
9. Displays, controls and communication
10. Acceleration, deceleration, and vibration
11. Escape and survival
12. Orientation
13. Man-machine-systems problems

The Armed Forces—NRC Committee on Bio-Astronautics, supported under the terms of a contract between the Air Force and the National Academy of Sciences, bears close resemblance in structure to similar Armed Forces-NRC Committees on Vision and Bio-Acoustics, both of which have been functioning for several years under the Academy-Research Council Division of Anthropology and Psychology.

The National Academy of Sciences-National Research Council is a private, nonprofit organization of distinguished scientists dedicated to the furtherance of science and its use for the general welfare. Although it is not a governmental organization, the Academy-Research Council has long enjoyed a close association with many Government agencies; its congressional charter, signed in 1863 by President Abraham Lincoln, calls upon the Academy to advise the Government, upon request, in all matters of scientific and technical interest.

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2. Psychiatric Evaluation of Candidates for Space Flight [1]

(A Paper by George E. Ruff, Captain, USAF (MC) and Edwin Z. Levy, Captain, USAF (MC), Stress and Fatigue Section, Biophysics Branch, Aero Medical Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio)

The high levels of stress expected in space flight require careful screening of potential pilots by psychological and physiological techniques. Since emotional demands may be severe, special emphasis must be placed on psychiatric evaluation of each candidate for a space mission.

The selection process begins with a detailed analysis of both the pilot's duties and the conditions under which he will carry them out. As long as we have had no direct experience with space flight, some aspects of this analysis will necessarily be speculative. We must thus rely heavily on knowledge of behavior during stress situations in the past. As a result, data from military operations, survival experiences, and laboratory experiments have guided the choice of men for space missions now being planned.

Although striking exceptions are seen, the individuals who have done best under difficult circumstances in the past have been mature and emotionally stable. They have usually been able to harmonize internal needs with external reality in an effective manner. When subjected to stress, anxiety has not reached high enough levels to paralyze their activity.

After the requirements of the mission and the qualifications of the individual best suited to accomplish it have been decided, it is necessary to select measures for determining who has the most of each desirable characteristic and the least of each undesirable characteristic. This can be done by using interviews and projective tests to give an intensive picture of each individual. Objective tests supplement the personality evaluation and measure intellectual functions, aptitudes, and achievements. After examination of the background data, interview material, and tests results, clinical judgment is used to decide which men are psychologically best qualified for the assignment.

[1] For presentation to 115th annual meeting, the American Psychiatric Association, Philadelphia, Pa., Apr. 29, 1959.

As firsthand knowledge of space flight increases, these procedures must be reexamined. When enough data have accumulated, predictions can be checked against performance criteria. Methods which predicted accurately will be retained and improved. Those with little value will be discarded. New measures can be added on the basis of increasing experience. Once correlation between psychological variables and the quality of performance have been determined, the accuracy of future selection programs should be raised.

A clinical approach of this type was used in selecting pilots for the first U.S. manned satellite experiment—NASA's Project Mercury. The objective was to choose men for a 2-year training program, followed by a series of ballistic and orbital flights. The pilot's duties will consist largely of reading instruments and recording observations. However, he will retain certain decision-making functions, and will be required to adapt to changing conditions as circumstances may demand.

By combining data on the nature of this mission with information on behavior during other stressful operations, the following general requirements were established:

(1) Candidates should have a high level of general intelligence, with abilities to interpret instruments, perceive mathematical relationships, and maintain spatial orientation.

(2) There should be sufficient evidence of drive and creativity to insure positive contributions to the development of the vehicle and other aspects of the project as a whole.

(3) Relative freedom from conflict and anxiety is desirable. Exaggerated and stereotyped defenses should be avoided.

(4) Candidates should not be overly dependent on others for the satisfaction of their needs. At the same time, they must be able to accept dependence on others when required for the success of the mission. They must be able to tolerate either close associations or extreme isolation.

(5) The pilot should be able to function when out of familiar surroundings and when usual patterns of behavior are impossible.

(6) Candidates must show evidence of ability to respond predictably to foreseeable situations, without losing the capacity to adapt flexibly to circumstances which cannot be foreseen.

(7) Motivation should depend primarily on interest in the mission rather than on exaggerated needs for personal accomplishment. Self-destructive wishes and attempts to compensate for identity problems or feelings of inadequacy are undesirable.

(8) There should be no evidence of impulsivity. The pilot must act when action is appropriate, but refrain from action when inactivity is appropriate. He must be able to tolerate stress situations positively, without requiring motor activity to dissipate anxiety.

The chances of finding men to meet these requirements were increased by the preselection process. Eligibility for the mission was restricted to test pilots who had repeatedly demonstrated their ability to perform functions essential for the Mercury project. Records of men in this category were reviewed to find those best suited for the specific demands of the mission. A group of 69 were then invited to volunteer. The 55 who accepted were given a series of interviews and psychological tests. On the basis of these data, 32 were chosen for the final phase of the selection program. This phase was designed to evaluate each candidate's medical and psychological status, as well as to determine his capacity for tolerating stress conditions expected in space flight.

The psychological evaluation included 30 hours of psychiatric interviews, psychological tests, and observations of stress experiments. The information obtained was used to rate candidates on a 10-point scale for each of 17 categories. Ratings were made on the basis of specific features of behavior—both as indicated by the past history and as observed during the interviews. Even though the general population was used as a reference group, the scales are normative only in an arbitrary sense. The 10 levels represent subjective decisions on which characteristics are ideal, which are average and which are undesirable. Although the reliability among raters is excellent, validation studies have not yet been done.

The categories are:

(1) Drive: An estimate of the total quantity of instinctual energy.

(2) Freedom from conflict and anxiety: A clinical evaluation of the number and severity of unresolved problem areas and of the extent to which they interfere with the candidate's functioning.

(3) Effectiveness of defenses: How efficient are the ego defenses? Are they flexible and adaptive or rigid and inappropriate? Will the mission deprive the candidate of elements necessary for the integrity of his defensive system?

(4) Free energy: What is the quantity of neutral energy? Are defenses so expensive to maintain that nothing is left for creative activity? How large is the "conflict-free sphere of the ego"?

(5) Identity: How well has the candidate established a concept of himself and his relationship to the rest of the world?

(6) Object relationships: Does he have the capacity to form genuine object relationships? Can he withdraw object cathexes when necessary? To what extent is he involved in his relationships with others?

(7) Reality testing: Does the subject have a relatively undistorted view of his environment? Have his life experiences been broad enough to allow a sophisticated appraisal of the world? Does his view of the mission represent fantasy or reality?

(8) Dependency: How much must the candidate rely on others? How well does he accept dependency needs? Is separation anxiety likely to interfere with his conduct of the mission?

(9) Adaptability: How well does he adapt to changing circumstances? What is the range of conditions under which he can function? What are the adjustments he can make? Can he compromise flexibly?

(10) Freedom from impulsivity: How well can the candidate delay gratification of his needs? Has his behavior in the past been consistent and predictable?

(11) Need for activity: What is the minimum degree of motor activity required? Can he tolerate enforced passivity?

(12) Somatization: Can the candidate be expected to develop physical symptoms while under stress? How aware is he of his own body?

(13) Quantity of motivation: How strongly does he want to participate in the mission? Are there conflicts between motives—whether conscious or unconscious? Will his motivation remain at a high level?

(14) Quality of motivation: Is the subject motivated by a desire for narcissistic gratification? Does he show evidence of self-destructive wishes? Is he attempting to test adolescent fantasies of invulnerability?

(15) Frustration tolerance: What will be the result of failure to reach established goals? What behavior can be expected in the face of annoyances, delays, or disappointments?

(16) Social relationships: How well does the subject work with a group? Does he have significant authority problems? Will he contribute to the success of missions for which he is not chosen as pilot? How well do other candidates like him?

(17) Overall rating: An estimate of the subject's suitability for the mission. This is based upon interviews, test results, and other information considered relevant.

It can be seen that categories 1, 2, 4, and 10 are largely economic constructs; 3, 5, 6, and 7 are ego functions; while the rest are specific characteristics considered important for space flight. The categories represent many different levels of abstraction and are not independent dimensions. In the final analysis. they are less a means of quantifying data than of organizing their interpretation. Not only do they provide a method to compare one subject with another, but also tend to focus attention on the material most closely related to the mission requirements.

An initial evaluation of each man was made by two psychiatrists, through separate interviews during the preliminary screening period. One interview was devoted primarily to a review of the history and current life adjustment, while the other was relatively unstructured. Finally, ratings were compared, information pooled, and a combined rating made. Areas of doubt and disagreement were recorded for subsequent investigation.

The men accepted for the final screening procedure were seen again several weeks later, after an intensive evaluation of their physical status had been completed. Each candidate was reinterviewed and the following psychological tests were administered:

Measures of motivation and personality

(1) Rorschach.
(2) Thematic apperception test.
(3) Draw-a-person.
(4) Sentence completion test.
(5) Minnesota multiphasic personality inventory.

(6) Who am I?: The subject is asked to write 20 answers to the question, "Who am I?" This is interpreted projectively to give information on identity and perception of social roles.
(7) Gordon personal profile: An objective personality test yielding scores for "ascendency," "responsibility," "emotional stability," and "sociability."
(8) Edwards personal preference schedule: A forced-choice questionnaire measuring the strengths of Murray's needs.
(9) Shipley personal inventory: Choices are made from 20 pairs of self-descriptive statements concerning psychosomatic problems.
(10) Outer-inner preferences: A measure of interest in and dependence on social groups.
(11) Pensacola Z-scale: A test of the strength of "authoritarian" attitudes.
(12) Officer effectiveness inventory: A measure of personality characteristics found in successful Air Force officers.
(13) Peer ratings: Each candidate was asked to indicate which of the other members of the group who accompanied him through the program he liked best, which one he would like to accompany him on a two-man mission, and which one he would assign to the mission if he could not go himself.

Measures of intellectual functions and special aptitudes

(1) Wechsler adult intelligence scale.
(2) Miller analogies test.
(3) Raven progressive matrices: A test of nonverbal concept formation.
(4) Doppelt mathematical reasoning test: A test of mathematical aptitudes.
(5) Engineering analogies: A measure of engineering achievement and aptitudes.
(6) Mechanical comprehension: A measure of mechanical aptitudes and ability to apply mechanical principles.
(7) Air Force officer qualification test: The portions used are measures of verbal and quantitative aptitudes.
(8) Aviation qualification test (USN): A measure of academic achievement.
(9) Space memory test: A test of memory for location of objects in space.
(10) Spatial orientation: A measure of spatial visualization and orientation.
(11) Gottschaldt hidden figures: A measure of ability to locate a specified form imbedded in a mass of irrelevant details.
(12) Guilford-Zimmerman spatial visualization test: A test of ability to visualize movement in space.

In addition to the interviews and tests, important information was obtained from the reactions of each candidate to a series of stress experiments simulating conditions expected during the mission. Neither the design of these tests nor the physiological variables measured will be discussed. Phychological data were derived from direct observation of behavior, postexperimental interviews, and administration before and after each run of alternate forms of six tests of perceptual and psychomotor functions. These procedures were:

(1) Pressure suit test: After dressing in a tightly fitting garment designed to apply pressure to the body during high altitude flight, each candidate entered a chamber from which air was evacuated to simulate an altitude of 65,000 feet. This produces severe physical discomfort and confinement.
(2) Isolation: Each man was confined to a dark, soundproof room for 3 hours. While this brief period is not stressful for most people, data are obtained on the style of adaptation to isolation. This procedure aids in identifying subjects who cannot tolerate enforced inactivity, enclosure in small spaces or absence of external stimuli.
(3) Complex behavior simulator: The candidate was required to make different responses to each of 14 signals which appeared in random order at increasing rates of speed. Since the test produces a maximum of confusion and frustration, it measures ability to organize behavior and to maintain emotional equilibrium under stress.
(4) Acceleration: The candidates were placed on the human centrifuge in various positions and subjected to different G loads. This procedure leads to anxiety, disorientation, and blackout in susceptible subjects.
(5) Noise and vibration: Candidates were vibrated at varying frequencies and amplitudes and subjected to high energy sound. Efficiency is often impaired under these conditions.
(6) Heat: Each candidate spent 2 hours in a chamber maintained at 130°. Once again, this is an uncomfortable experience during which efficiency may be impaired.

After all tests were completed, an evaluation of each man was made by a conference of those who had gathered the psychological data. Final ratings were made in each category described previously, special aptitudes were considered, and a ranking within the group was derived. By combining the psychiatric evaluations, results of the physical examinations and physiological data from the stress test procedures, the group was subdivided under the headings "Outstanding," "Recommended," and "Not Recommended." Finally, seven men were chosen from the list according to the specific needs of the Mercury project.

IMPRESSIONS OF CANDIDATES FOR SPACE FLIGHT

Although the results of the selection program can't be assessed for several years, impressions derived from psychiatric evaluations of these candidates are of interest. In answer to the question, "What kind of people volunteer to be fired into orbit?" one might expect strong intimations of psychopathology. The high incidence of emotional disorders in volunteers for laboratory experiments had much to do with the decision to consider only candidates with records of effective performance under difficult circumstances in the past. It was hoped that avoiding an open call for volunteers would reduce the number of unstable candidates.

In spite of the preselection process, we were surprised by the low incidence of such disorders in the 55 candidates who were interviewed. For the 31 candidates who survived the initial screening and physical examination, repeat interviews and psychological tests confirmed the original impressions. There was no evidence for a diagnosis of psychosis, clinically significant neurosis, or personality disorder in any member of this group.

Certain general comments can be made concerning the 31 men who received the complete series of selection procedures. The mean age was 33, with a range from 27 to 38. All but one were married. Twenty were from the Midwest, Far West, or Southwest. Only two had lived in large cities before entering college. Twenty-seven were from intact families. Twenty were only or eldest children. (In this connection, it is perhaps worth noting that four of the seven men chosen are named "junior.") Pronounced identifications with one parent were about equally divided between fathers and mothers, although mothers with whom such identifications were present were strong, not infrequently masculine figures.

Impressions from the interviews were that these were comfortable, mature, well-integrated individuals. Ratings in all categories of the system used consistently fell in the top third of the scale. Reality testing, adaptability, and drive were particularly high. Little evidence was found of unresolved conflict sufficiently serious to interfere with functioning. Suggestions of overt anxiety were rare. Defenses were effective, tending to be obsessive-compulsive, but not to an exaggerated degree. Most were direct, action-oriented individuals, who spend little time introspecting.

Although dependency needs were not overly strong, most showed the capacity to relate effectively to others. Interpersonal activities were characterized by knowledge of techniques for dealing with many kinds of people. They do not become overly involved with others, although relationships with their families are warm and stable.

Because of the possibility that extreme interest in high performance aircraft might be related to feelings of inadequacy in sexual or other areas, particular emphasis was placed on a review of each candidate's adolescence. Little information could be uncovered to justify the conclusion that unconscious problems of this kind were either more or less common than in other occupational groups.

A high proportion of these men apparently passed through adolescence in comfortable fashion. Most made excellent school and social adjustments. Many had been class presidents or showed other evidence of leadership.

Most candidates entered military life during World War II. Some demonstrated an unusual interest in flying from an early age, but most had about the same attitudes toward airplanes as other American boys. Many volunteered for flight training because it provided career advantages or appeared to be an interesting assignment.

Candidates described their feelings about flying in a variety of terms: "something out of the ordinary," "a challenge," "a chance to get above the hubbub," "a sense of freedom," "an opportunity to take responsibility." A few look upon flying as a means of proving themselves or to build confidence. Others consider it a "way for good men to show what they can do."

Although half the candidates volunteered for training as test pilots, the others were selected because of achievements in other assignments. Most view test flying as a chance to participate in the development of new aircraft. It enables them to combine their experience as pilots and engineers. Their profession is aviation and they want to be in the forefront of its progress. Danger is admitted, but deemphasized—most feel nothing will happen to them. But this seems to be less a wishful fantasy than a conviction that accidents can be avoided by knowledge and caution. They believe that risks are minimized by thorough planning and conservatism. Very few fit the popular concept of the daredevil test pilot.

Although attempts have been made to formulate the dynamics underlying the pursuit of this unusual occupation, generalizations are difficult to make. Motives vary widely. While it is clear that conscious reasons may be unrelated to unconscious determinants, the variation in conscious attitudes illustrates the impossibility of a single explanation for a career which has different meanings for different individuals. One man, for example, stated that he enjoys flight testing because it allows him to do things which are new and different. He enjoys flying the newest aircraft available—vehicles that most pilots will not see for several years. Another is an aeronautical engineer who is primarily interested in aircraft design. He looks upon a flight test much as the researcher views a laboratory experiment.

Reasons for volunteering for Project Mercury show a mixture of professionalism and love of adventure. Candidates are uniformly eager to be part of an undertaking of vast importance. On one hand, space flight is viewed as the next logical step in the progress of aviation; on the other, it represents a challenge. One man expressed the sentiments of the group by saying, "There aren't many new frontiers. This is a chance to be in on one of them." Other expressions included: "a new dimension of flight," "a further stage in the flight envelope of the manned vehicle," "a chance to get your teeth into something big," "the sequel to the aviation age," a "contribution to human knowledge," "an opportunity for accomplishment," "the program of the future," "an interesting, exciting field," "a chance to be on the ground floor of the biggest thing man has ever done."

At the same time, most candidates were practical. They recognized that this project will benefit their careers. To some it is a chance to insure an interesting assignment. Most recognize the trend away from conventional manned aircraft and look upon the Mercury project as a means for getting into the midst of future developments. One said: "We're the last of the horse cavalry. There aren't going to be many more new fighters. This is the next big step in aviation. I want to be part of it." Most are aware of the potential personal publicity and feel this would be pleasant, but "not an important reason for volunteering."

Although all candidates are eager to make the flight, it is not their only concern. Most want to participate in development of the vehicle and have an opportunity to advance their technical training. The orbital ride is partly looked upon as a chance to test an item of hardware they have helped develop. Risks are appreciated, but accepted. Most insist they will go only when the odds favor their return. No one is going up to die. They are attracted by the constructive rather than the destructive aspects of the mission.

Psychological tests of these 31 men indicate a high level of intellectual functioning. For example, the mean full-scale scores for the seven who have been selected range from 130 to 141, with a mean of 135. The pattern is balanced, with consistently high scores on both verbal and performance subtests.

Projective measures suggest the same healthy adaptations seen in the interviews. Responses to the Rorschach, for example, were well organized. Although not overly rigid, they did not suggest much imagination and creativity. Aggressive impulses tended to be expressed in action rather than fantasy.

Behavior during the isolation and complex behavior simulator tests—which might be considered input-underload and input-overload situations—showed evidence of great adaptability. No candidate terminated isolation prematurely and none viewed it as a difficult experience. As might be expected for this brief exposure, no perceptual changes were reported. Fifteen subjects "programed" their thinking in isolation. In five of these men, the attempt to organize thoughts was considered evidence of an overly strong need for structuring. Sixteen permitted random thought, relaxed and enjoyed the experience. Most slept at least part of the time.

When placed under opposite conditions—with too much to do instead of too little—the candidates were usually able to keep from falling hopelessly behind the machine. Only a few were troubled by the impossibility of making all responses promptly. The majority became content to do as well as possible, showing a gradually increasing level of skin resistance, even though working at a frantic pace.

Reactions to physiological stressors correlated positively with the psychiatric evaluations. Candidates who had been ranked highest on psychological variables tended to do best in acceleration, noise and vibration, heat, and pressure chamber runs. Their stress tolerance levels were among the highest of the hundreds of men subjected to these procedures in the past. Uncomplaining acceptance of the discomforts and inconviences of this phase of the program appeared to reflect not only their strong motivation, but also their general maturity and capacity to withstand frustration.

In summary, it is suggested that the most reasonable approach to selecting men for doing something no one has done before is to choose those who have been successful in demanding missions in the past. To decrease the probability of error, a broad sample of behavior must be observed. Every effort should be made to make these observations as relevant to the expected demands of the mission as possible.

By selecting only those candidates who were able to adapt to whatever conditions confronted them, we hope we have found those who are best qualified for space flight. Our confidence is further strengthened by the attitudes of the men who were chosen. Most reflected the opinion of the candidate who, when asked why he had volunteered, explained: "In the first 50 years since the Wright brothers, we learned to fly faster than sound and higher than 50,000 feet. In another 5 years we doubled that. Now, we're ready to go out 100 miles. How could anyone turn down a chance to be part of something like this?"

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3. Man in Space . . . Where We Stand

(By Col. Paul A. Campbell, Chief, Space Medicine Division, School of Aviation Medicine, U.S. Air Force [1])

Those of us associated with research toward the goal of manned spaceflight feel that its eventual accomplishment is inevitable and that its accomplishment is a logical, rational development in the evolution of man and the evolution of the metagalactic universe.

Man has certain attributes, physiological, psychological, and sociological, which have resulted in rational, step-by-step progress toward space. A few of these are:

His natural curiosity which constantly asks him what lies beyond the clouds, the blue sky, and the stars.

His spirit of adventure from which he may gain enjoyment from going places and doing things outside the ordinary. In many cases he enjoys sufficient danger to separate him from the "meek who shall inherit the earth."

His refusal to be contained by barriers which restrict him or his activities.

His quest for achievement of which he, his family, etc., can be proud, which again sets him apart from his fellow men and improves his ego.

His built-in desire to do that which he has been told is impossible.

How far man will go into space probably (and here we have all learned to couch our dogmatism with "probably") will be found to be limited to some extent at least by—

The speed of light.

The distance which he can travel and return in his productive life span. Unless he changes considerably, he will always wish to return to tell or write about his feats.

The limits of resupply within reasonable time.

The amount of radiation which he can be exposed to and remain in good health.

The statistical chances of survival, etc.

This is all well and good and gives us a framework for the future and feeds fuel to the science-fiction writers, but the cold gray dawn of each morning tells us that there is much to be done before spaceflight in its broader sense can be accomplished. We are progressing in a step-by-step fashion, but at times two steps forward and one step backward. Our forward steps sometimes bring us face to face with a new barrier, such as the Van Allen-type radiation bands, but new knowledge tempers the old and progress continues. In [our] time * * * we have seen the oxygen barrier, the bends barrier, the vapor-pressure barrier, the sound barrier, the thermal barrier, the ozone barrier, and many others appear for a time to block the extension of aviation, but each has vanished as some new breakthrough has shown the means of traverse.

Progress in each parameter has been exponential. The pauses produced by barriers have resulted in such short-lived plateaus that when viewed in the curve of progress of the 20th century—59 years to date—they seem almost

[1] Air Force and Space Digest, July 1959, pp. 65–67.

imperceivable. Aviation through rocketry, its Newtonian principle of propulsion, its lift produced by propellant rather than wings, and its ability to carry its oxidizer rather than to depend upon the atmosphere for its breath, now gives us the means for penetrating the atmospheric barrier. Where machine can go, man wishes to go and will discover, invent, or improvise the means.

But again to get back to our earth-bound laboratories and our mundane existence, let us have a look at where we stand today and point out a few of the more serious problems which slow progress toward spaceflight and require integrated, concentrated effort. Let us do a little curve watching before we look into the crystal ball.

Man and machine have been in a more or less continuous race to outdo one another since the advent of aviation. At times man, through advancements of the state of the art of protective devices and measures, has been in the lead and could go where the machine could not take him. At times the machine has been in the lead and has been able to go places and do things in which man could not participate.

Until 2 or 3 years ago the race between the aviation designers and engineers on the one hand and the flight surgeons, aviation biologists, and human factors groups on the other hand has been nip and tuck. But in these past 2 or 3 years the situation has suddenly changed, and the machine capability has advanced far beyond man's capability. Let us look at two parameters to see where we stand.

Manned altitude, or, as we must now say, distance outward, achievement has been one parameter which has been carefully watched since the Wright brothers' first flight. * * * The curve is exponential and looks good when viewed on the proper chronological base line. It ended with Kincheloe's flight [in the Bell X–2] to an altitude of 126,200 feet. But when placed within the framework of hardware achievement, it does not look so good. The man/machine gap is tremendous and is lengthening by the month.

Let us now look at another parameter—that of speed—because as we all know man cannot orbit until he reaches a speed of some 18,000 miles per hour and cannot escape the earth's gravitational tentacles until his velocity has reached some 25,000 miles per hour. First, let us examine man's speed achievements plotted chronologically. It ends with Mel Apt's fatal flight [also in the X–2] reaching about 2,148 miles per hour. Again we have an exponential curve and man appears to be doing just fine. But again, when viewed within the framework of hardware achievement, it does not look very good, and again we see a tremendous man/machine gap.

Now why has this gap lengthened so much in the past few years. I think we can point to one situation—a comparison of resources—scientists and facilities—a comparison between the hardware development area and the human factors development area. Whereas there are several thousand scientists and facilities in hardware research, design, and production, there are still only a few in space medicine, space biology, human factors, and related disciplines, and this is taking its toll in terms of integrated progress toward manned spaceflight.

The space concept is a relatively new one and is interdisciplinary throughout. Consequently, training for those who wish to participate simply does not exist except in the in-house, or on-the-job categories. Programs for training require the wedding of diverse disciplines such as astronomy and biology, astrophysics and ecology, logistics and ecology. As an example, may I point to the organizational chart of our own Space Medicine Division at the School of Aviation Medicine, USAF, to illustrate:

SPACE MEDICINE DIVISION

1. Bioastronautics:
    - Utilization of the energies of space.
    - Protection against energies of space.
    - Extraterrestrial and cosmic radiation.
    - Liaison.
2. Astroecology:
    - Ecological systems.
    - Components.
    - Ecologistics.
    - Synecology.
    - Psychological reactions.
    - Selection.
    - Training.
    - Indoctrination.

3. Biogravics:
   - Biodynamics.
   - Zero and sub "G."
   - Acceleration.
   - Deceleration.
   - Tangential acceleration.
   - Reaction control.
4. Bioastrophysics:
   - Instrumentation.
   - Design.
   - Maintenance.
   - Weight and capacity reduction.
   - Reentry.

The wedding of the disciplines here is self-evident.

May I now emphasize that the primary biological problem of manned spaceflight at this time lies in the production of people trained in the required interdisciplinary techniques and with imagination, who in turn can help produce solutions to the many complex problems which plague us.

Let us now have a look at some of the other problems in the production of a reliable manned space system and see where we stand today:

The problem of reentry is very serious as it involves relatively rapid slowdown from speeds (in the neighborhood of 18,000 miles per hour if orbiting or some 25,000 miles per hour if in escape ellipse) to zero miles per hour. If we take the example of the orbiting vehicle, the magnitude of the total energies is some 19 million foot-pounds per pound of orbiting mass. Thus, approximately 24,000 B.t.u.'s per pound of orbiting mass must be dissipated in a relatively short period of time. For comparison, the energy contained in a gallon of gasoline is about 21,000 B.t.u.'s per pound. During the same period high G loads approaching man's tolerance limits will have to be sustained. Project Mercury, the first orbiting manned spacecraft, will have to meet these requirements. Its engineers say it can be done.

Radiation.—Orbiting beneath the Van Allen bands, yet remaining above the levels of appreciable atmospheric drag, is possible. This requires an almost circular orbit between the altitudes of something like 140 miles and 400 miles. For travel into the deeper reaches of space, polar launching, to avoid the Van Allen bands, would require an exit passage almost identical with the path or entrance corridor of the maximum concentration of incoming heavy primaries. Again in the type of space travel of the relatively near future, orbiting within these bounds for short periods seems feasible.

Weightlessness.—This is another huge question mark as our simulation capability through the use of parabolic flight patterns still remains under something of the order of 60 seconds. We cannot even guess as to the effects of several hours or several days of zero G. Several of us are of the opinion, however, that an even greater problem is for the engineers to provide an absolutely stable platform which will not produce some tangential G due to rotation or tumbling. Weightlessness is possibly the lesser of the two evils.

Closed ecological systems.—For space travel of short duration such as a few circuits of the earth closed-loop ecological systems are unnecessary, but for long flights involving months such a system is an absolute requirement as resupply will be very difficult and the logistics will be exorbitant.

Human logistics of spaceflight other than resupply require capacity reduction through miniaturization, the conservation of everything, recycling, and reutilization wherever possible. There is much to be done here and it must be done as the weight costs, in terms of fuel and structure required for getting each pound of man, oxygen, food, containers, fluid, protective gear, etc. (into space), are very high.

Escape from a space vehicle in the event of accident, recovery, and survival present huge problem areas. The problems have been analyzed. The answer probably lies in constant improvement of the reliability of the primary vehicle.

(Colonel Campbell is a pioneer in the aeromedical field, having twice served as Director of Research at the School of Aviation Medicine and more recently as special assistant to the commander of the Air Force Office of Scientific Research. This article is condensed from a presentation to the Federation of American Societies for Experimental Biology in April 1959. It reflects the author's personal views and is not to be construed as a statement of official U.S. Air Force policy.)

APPENDIX C

The Public Impact of Early Satellite Launchings

1. Summary of the Findings

[Excerpt from "Satellites, Science and the Public: A Report of a National Survey on the Public Impact of Early Satellite Launchings, for the National Association of Science Writers." Ann Arbor. Survey Research Center, Institute for Social Research, the University of Michigan, 1959, ch. v pp. 50–52. Printed with permission.]

The finding that almost half the adult population of the United States became aware of the satellites in a single year set the stage for the analysis. Over 90 percent had heard of the satellites by mid-1958 as compared to less than 50 percent a year before.

Less than one-third of those who were aware of the satellites thought of them as having primarily an immediate scientific purpose. Other purposes which many people attributed to the satellites were their use in competition with Russia and their potential use in future space travel. About one-fourth of those who had heard of the satellites were unable to think of a purpose.

Education, income, and the number of media used by the person were found to be good predictors of satellite awareness and purpose. The higher the education level, the more the income, and the greater the number of media used, the more likely was satellite awareness and the attribution of a scientific purpose.

Relatively little change between studies was shown in answers to questions regarding the use of the mass media. Within the newspaper audience there was a moderate increase in readership of science; however, the ranking of this item in relation to other news categories changed only slightly. No change was shown for the reading of medical news.

An overwhelmingly favorable evaluation of science and scientists was shown for both surveys. Little change in any table was noted with the exception of a 15-percent decline in the mentioning of a "higher standard of living" as a good effect of science. The economic recession which was current in the postsputnik survey was offered as a possible explanation of this change. The extent of similarity between the samples was remarkable in: net impact of science; responsibility for the bad effects of science; and the personal characteristics and motivation attributed to scientists.

A majority of respondents in the postsputnik sample were shown to give no clear edge to either America or Russia in the science race. One out of three differentiated areas of science in saying that the United States was ahead in some areas, Russia in others. Only 1 person in 10 thought Russian science to be superior. This contrasts to the 26 percent who said so 1 month after Russia launched Sputnik I.

More than one-half of the postsputnik sample stated a preference for medical science when asked which of four projects listed they would choose if money were available for only one. One-third chose juvenile delinquency research. Only 7 percent chose basic research and 3 percent picked "putting the first man on the moon."

The higher the education and the greater the extent of science reading the more frequent was the differentiation of areas of science and the choosing of basic research as a project.

In attempting to bring some sort of order and generality out of the data presented in this report, it seems necessary to take the specific cases of the earth satellites and to point out similarities and differences between this and other scientific news events.

Scientific break throughs are reported almost daily in all of the mass media. In this sense, the satellite launchings were no different from a great amount of other science news. The satellite news, however, differed in many ways. The sheer volume of news presented was tremendous. Secondly, it had elements of suspense not usually found in scientific achievement—the public could often wait for hourly bulletins of the progress of the U.S. satellite launchings.

The satellites, further, constituted a series of events stretched over the 7-month period right up to the time of the postsputnik survey. Thus the initial event was continually being reinforced by new events entering into the public view. The launchings, if realized in the scientific sense, had ramifications for all areas of science. A person with an avid interest in medicine, for example, could have found in the satellite news ample information in the medical area alone to sustain his active interest.

Another unusual feature was the combination within a single series of news events of the irreality of the science-fiction-like subject matter and of the reality afforded through the possibility of direct observation. People may not have seen sputnik, but a great number certainly knew someone who had seen it. Finally, the launchings were tied to many media content areas not directly scientific. The strategic military and foreign affairs aspects undoubtedly heightened satellite interest.

The satellite news had in common with other science news items a similar precondition of the audience. Habitual mass media patterns, the existing channels of interpersonal communications, and the personal "filters" through which information is received are all factors limiting the unusual qualities of the satellite news.

Given the preceding similarities and differences of the earth satellites and other forms of science news, what are the implications of these findings for the science writer? At least five generalizations may be advanced. Most of these are well known to the science writer and are part of the everyday business of communicating to an audience; however, they require documentation and such is partially presented by the data of this study.

1. Awareness of a scientific event or finding may be stimulated in all strata of the public if enough news concerning the event can be made available to the audience. Even people with low education and low interest in science will develop at least vague notions that the event has taken place if the volume of content is great enough.

2. It is likely that the public reaction to a scientific event is largely motivated by a desire to understand and master the world as seen by the individual. Each person will accomplish this in the way most satisfying to him, which may mean incorporating the event with concepts of a nonscientific nature when scientific ones aren't known or are subordinated to other concerns.

3. Increase of interest in a particular area of science due to a major breakthrough in knowledge or achievement is not likely to stimulate interest in other scientific areas without the public seeing definite links between the two areas. In the present study, medical news showed no increase in interest.

4. The pattern of public reactions to science and scientists is a complex and pervasive phenomenon. The generally favorable attitude toward science and scientists may be viewed as more stable than the public's notions of the boundaries of scientific endeavor. In the present study, the lack of fixed boundaries was illustrated by the large decrease in the percentage giving a high standard of living as an outcome of science.

5. Science and scientific events do not operate in a vacuum. While a certain amount of public inertia makes mass panic unlikely, there are certain aspects of the public's evaluation of science that are not immune to change. Shortly after Sputnik I, before our Explorers and Vanguard were launched, the public appeared genuinely concerned, and over one-fourth conceded Russian science great superiority. The successful American launchings seemed to have dissipated much of this concern just a few months later. Six months after Sputnik I, only 10 percent thought Russian science was superior, and of these people only 1 in 20 gave basic research or the man-on-the-moon project as their preferred research. It seems likely that the public is less concerned with what science is than with what it accomplishes.

APPENDIX D

Unofficial Statements and Observations Regarding Manned Space Flight Developments in the U.S.S.R.

1. Excerpt From Transcript of Interview in Moscow by Visiting American Students and by Irving R. Levine, Bureau Chief of the National Broadcasting Co. in the Soviet Union, With Dr. Anatoli Blagonravov, Academician, Member of the Soviet Academy of Sciences, October 5, 1958

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Question. Professor, do you plan to launch a man-carrying satellite in the near future?

Dr. Blagonravov. In launching the sputnik we will first of all be fulfilling the program which was mapped for the IGY. It is natural that the launching of every sputnik gives us more and more new data and therefore the program will be developing with the launching of every new satellite. Sooner or later most probably we will be able to send up a man-carrying sputnik that will be circling the earth. I can't say when that will be at present.

Question. What would be the probabilities of retrieving such a satellite?

Dr. Blagonravov. Our scientists are working on this problem at present and most probably it will be solved in time.

Mr. Levine. May I interject a question here, which I am sure interests many American youths: If there is a failure in such a launching, will it be announced?

Dr. Blagonravov. Up until now we have had no failures. We hope that we will meet with no failures and all measures are being taken to make the launching of every sputnik a success.

Question. What information have you gained in medical science from Laika, the sputnik dog?

Dr. Blagonravov. Physiologists were very interested in knowing how Laika would behave when sputnik reached its orbit, how it would behave in the flight to the orbit and how it would stand the state of weightlessness. The data we received was very favorable in that respect. As long as the apparatus on the sputnik was working and was sending down the information to earth, we knew that Laika felt normally and everything was going just as it should.

Mr. Levine. Professor Blagonravov, Laika was the first dog entering into space. Will the first man into space be a Soviet man?

Dr. Blagonravov. We hope that the first man in the cosmos will be a Soviet man.

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2. Excerpt From Prof. S. Fred Singer's "The Use and Uselessness of Outer Space," in The Reporter, June 11, 1959, Pages 25–26

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Try to imagine the headline: "Russians Put Two Men in Orbit." Not just one; they are capable of putting up two or even more, and they know the jolt it would give world opinion. One man is just a man—but two men make up a crew. Imagine that these men are able to converse in English, are able to recognize signals from the ground. Imagine that they will perform all sorts of functions, ranging from broadcasting propaganda to answering questions addressed to them, reporting forest fires, and so on. It is hard to overestimate the impact this would have.

There is the tremendous danger that the Russian manned satellites will be represented to people as a great military achievement, that the men in orbit will be represented as the masters of the world. They may occasionally spot a plane taking off, and this will be presented as proof that nothing escapes their view. A few such tricks, and a psychology of deep military inferiority might be impressed on the Western World.

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If, in addition, the Russians believe their own propaganda and acquire a feeling of tremendous military superiority, then conditions might be ripe for Soviet military adventures. It is decidedly in our interest, therefore, to inform the world, and especially the U.S. public, that a manned satellite is inevitable and that the Russians are likely to be first, but that this will have hardly any military significance.

WE WILL HAVE ONE TOO

It is my opinion that the Russians will try a manned satellite very soon. Judging from our own time scales, it should take only a year and a half to prepare a capsule design, test it, and work out a recovery scheme. The main obstacle to a manned satellite is, of course, a completely reliable launching rocket. This, the Russians assure us, they have already. Their straight-faced claim is that none of their sputnik rockets has ever failed. According to my calculations, then, they should have had a manned satellite up by now. Where is it? Perhaps their rockets are not all that reliable. Or could it be that they are having some other kind of trouble? In any case, if their claims are taken at face value, then their manned satellite is overdue.

Our own manned-satellite program has finally gone into operation after being shunted from agency to agency during the past year and a half. Its success will depend mainly on the availability of a reliable rocket booster; presumably the program can go into effect as soon as the Atlas booster has been fired often enough for us to be sure of its reliability. This may take some time; perhaps as many as a hundred firings will be necessary.

In the meantime it is rather surprising that all of our eggs are in one basket, and that only one technical approach to the manned capsule is being taken. It would be wiser if there were duplication or even triplication in our approach to a manned satellite. The capsule itself represents only a small part of the total cost of the program, and a competitive effort might give us a better chance of achieving ultimate success. We should remember the importance of the Jupiter rocket as a backup to the Vanguard satellite program.

From a purely psychological point of view and for prestige purposes, it is essential for us to make sure we can put a man into orbit at the earliest possible date irrespective of when the Russians succeed in their efforts. But since it is unlikely that we shall be first, it behooves us to make it clear to everyone that putting a man in space has nothing to do with the "control of space," whatever that means. Probably man's real function in space is simply to explore the universe he lives in.

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3. Soviet Affairs

(By Dr. Albert Parry [1])

The Red version of Project Mercury: How well has it fared compared with the choice and training of our seven astronauts? The Soviets say and publish very little on their part in this momentous race. They talk instead about the training and flights of their 12 dogs and 1 rabbit.

Yet, Soviet spacemen-in-training do exist: We hear that Moscow did sometime ago select five men for such conditioning. One of the five has since been killed in an accident, the nature of which had not been revealed. All five were World War II flyers, decorated for their feats in air combat. This much was told by Soviet space-medicine experts to our Brig. Gen. Don Flickinger, medical assistant to the commander of the U.S. Air Force's Air Research and Development Command, on the general's recent trip to Moscow.

Older than Project Mercury airmen: Russia's would-be spacemen were perhaps not as carefully selected as our seven candidates. General Flickinger concluded this, in part, from a certain surprise evidenced by the Soviet space-medicine men to whom he talked: they voiced their interest in the fact that the seven U.S. astronauts had particularly high IQ's. Was this a requirement? they asked. No, our general replied, it just happened that the American candidates who passed the stiff requirements of psycho-physical fitness have those high IQ's as well.

As to the Soviet yardsticks for their spacemen, it may be argued that if the Soviets had similar tough standards of psycho-physical fitness for their candidates, the latter might have also possessed keen intelligence and the Moscow doctors would not have been surprised by our men's IQ's.

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[1] In "Missiles and Rockets" July 27, 1959, p. 41.

On the other hand, we may speculate that the Soviet spacemen are not only flyers but have also been specifically trained in various advanced astro-sciences. This would make them almost invariably older than our men, and thus spared anything like our exacting standards of psycho-physical fitness applicable to younger men only. Yet, the older Soviet spacemen may be every inch of their brain as intelligent as our younger ones. The Moscow doctor's interest in our men's IQ's may be due to the fact that in Russia generally, IQ tests are seldom, if ever, used.

Soviet interest in Mercury is high. This is seen particularly from the recent article in Sovetskaya Aviatsia on American methods of selecting and training of "cosmonauts," written by Dr. V. Borisov, a space-medicine expert.

An American film shown in Moscow recently was judged as of great value to Dr. Borisov and his fellow space-medicine men. This was the movie brought by U.S. delegates to the May 25-June 1 conference of the International Aeronautical Federation held in the Soviet capital. Dr. Borisov wrote that during the period of weightlessness, shown in the film clearly by the floating of a few unattached objects in the plane's cabin, the American flyers who were being tested "worked on a special installation with a large number of buttons and levers"—and the Soviet viewers obviously admired our flyers' movements "which were quick and well coordinated."

Particular impression in Moscow was made by these U.S. ways to overcome weightlessness: Item 1—training an astronaut to float in the cabin during his weightlessness. This floating, Dr. Borisov observed, was done "dexterously," the floater's cycle of movements "greatly resembling the ordinary movements of a swimmer." Item 2—the use of special shoes with magnetic soles. Item 3—combating the difficulty of drinking liquids while weightless. Dr. Borisov wrote approvingly of special vessels from which U.S. astronauts squeezed water directly into their mouths.

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4. Soviet Recovers Three Space Animals—Two Dogs and a Rabbit Ride Into Upper Atmosphere—4,400-Pound Payload

(By Osgood Caruthers)

[From the New York Times, July 7, 1959]

Moscow, July 6.—The Soviet Union announced tonight that it had fired two dogs and a rabbit into outer space and had brought them safely back to earth.

The instruments and animals carried by the single-stage intermediate-range ballistic missile weighed more than 4,400 pounds the announcement said. Scientific commentators termed the payload the heaviest ever hurled into space.

Announcement of the launching was repeated over the Moscow radio at rapid intervals. It did not report how high the rocket had flown.

LAUNCHING LAST THURSDAY

It said it was the third time one of the dogs, named Otvazhnaya or Courageous, had been sent up in a rocket and returned. The other dog aboard the rocket was named Snezhinka, or Snowflake. The Russian names indicate that both dogs are female.

The launching took place July 2, according to the announcement.

Tass, the official press agency, said that the instruments aboard had sent back information on the animals' reaction to weightlessness as well as information on the ultraviolet part of the solar spectrum, the structure of the ionosphere and the direction and speed of airstreams at various altitudes.

The rescue equipment separated as planned, the announcement said, adding that the research objective had been fulfilled.

Earlier flights by the dogs had provided Soviet scientists with information on their adaptability to flight in the upper atmosphere, according to the announcement. It has been known for some time that Soviet rocketeers have been training dogs for such flights.

"A GREAT DAY FOR SOVIET"

The second Soviet satellite, launched more than a year ago, carried the dog Laika into orbit, where she died after several trips around the earth. That satellite later burned up in the atmosphere. The payload on that flight was 1,122 pounds.

"It is a great day for Soviet science," Moscow radio commented. "We have proved that cosmic radiation is no barrier to flights in outer space."

The Soviet announcers made no mention of U.S. success last month in firing two monkeys in a rocket and bringing them safely back to earth.

It was not known why Soviet officials had waited 4 days before announcing the flight and return of the three animals. However, the news provided a dramatic climax to the opening day of the International Cosmic Ray Conference in Moscow.

A broadcast of a football match was interrupted for the bulletin. The repetition of the announcement and the quickly following commentary by Soviet academicians on what they called "another triumph of Soviet science" indicated that officials here believed this to be an achievement of utmost importance, not only in missile launching but also regarding future space travel.

"This has proved that we can bring animals back alive," one commentator said. "It means much in the preparation for space flights by human beings."

It was with considerable gloating that the commentators also contended that the rocket was the most powerful single-stage device ever launched and was "much stronger than anything the Americans have."

The July 2 launching was exactly 6 months from the announcement of the firing of the Soviet moon rocket that went into orbit around the sun.

In describing the latest Soviet shot, the Moscow radio said:

"The launching took place in a normal way. The rescue system made certain the landing of the section that was separated from the rocket and the container with the scientific equipment and the experimental animals.

"According to preliminary information the program of investigation is fulfilled and valuable material has been obtained on all questions.

"For the first time, information was obtained about the composition of light gases in the atmosphere. The condition of the animals after landing is good."

RABBIT A NOVELTY

The chief novelty in the Soviet announcement was the listing of a rabbit on the passenger list.

Rocket flights by Soviet dogs have been repeatedly publicized. But no rabbit has turned up before.

A leading American scientist in the field suggested that the rabbit might have been included to find out what effect such flights might have on the reproductive process.

The scientist, Dr. Douglas Worf of the National Aeronautics and Space Administration, noted several advantages in using a rabbit in such research:

A female rabbit's gestation period is only about a month. Scientists might quickly learn how pregnancy was affected by weightlessness, cosmic rays and other phenomena encountered in space flight.

A female rabbit can bear young four to eight times a year. The effects of space flight on several generations of space passenger's descendants might be speedily determined.

A female rabbit can be made pregnant without the use of male sperm. This can be done by injection of salt water. Dr. Worf suggested that the process, known as parthenogenesis, might have been initiated in flight while the rabbit was weightless. He was not certain, however, that it would work except under the strictest laboratory conditions.

When this country recently launched the monkeys Able and Baker on a 1,700-mile flight down the Caribbean, one of the side experiments was a study of the fertilization process of the sea urchin. This is a small animal, often found underfoot on the beach, that sprouts pinlike protrusions.

From the point of view of rocket technology, the most significant aspect of the latest Soviet flight appeared to be the enormous size of the payload.

The Russians put the weight of animals and instruments at more than 4,400 pounds. They said this was the heaviest payload ever hurled into space.

5. Soviet Space Dog Survives Fourth Trip—Recovered With Companion and Rocket Instruments

(By Osgood Caruthers)

[From the New York Times, July 14, 1959]

Moscow, July 13.—The world's most traveled space dog has made another rocket flight into the upper atmosphere and returned safely to the Soviet Union.

The dog Otvazhnaya, or Courageous, was sent up with another canine astronaut

July 10 in a powerful single-stage ballistic missile carrying a payload of 4,840 pounds. This was announced in a bulletin from the official Soviet news agency Tass, broadcast over the Moscow radio at the end of this evening's regular news transmission.

ROCKET SIMILAR TO FIRST

Otvazhnaya, a pert little white female spitz, rode the first rocket into the upper atmosphere and back July 2 with another dog named Snezhnika, or Snowflake, and a rabbit. Announcements have said that Courageous made two previous flights in rockets, apparently of a preliminary or training nature.

The dog that flew with her in the second big rocket was not named. Why Snowflake was not chosen to make the second trip was not revealed.

Despite announcements following the first flight that the two dogs returned in excellent physical condition, Soviet newspapers and magazines at first published pictures showing only Courageous and the rabbit.

The announcement tonight said the July 10 probe into the outer atmosphere was made by a rocket similar to the first. However, the first carried a payload including instruments and the weight of the animals of only 4,400 pounds, or 440 pounds less than the second rocket.

The bulletin said the instruments of the second rocket had carried out the same research plans as the first one did. It also carried instruments for other studies.

MEASURED RADIATION

The broadcast said the second missile had "made measurements of infrared radiation of the earth and the earth's atmosphere, photographed masses of clouds over a large territory, simultaneously made an analysis of the ionic and neutral composition of the atmosphere and made measurements of the electrostatic field."

"The animals and instruments were recovered in good condition," the bulletin said "The payload of the rocket was 2,200 kilograms."

The animals original trip to the upper atmosphere was accompanied by boasts from Soviet scientists that the rocket had carried the heaviest payload of any single-stage intermediate missile in the world and that no other nation had one so powerful.

Like the announcement of the original flight, the second gave no details as to where this important scientific test had been made or how high the missile had flown before the container carrying the animals and instruments was separated from the rocket and brought back safely to earth.

However, Grigory K. Khrushchev, a corresponding member of the Soviet Academy of Sciences (apparently unrelated to the Soviet Premier) wrote in the latest issue of Literatura i Zhizn (Literature and Life), that the first flight had obtained valuable information on physcial functions of the animals "at great height or in the order of several hundreds of kilometers."

The announcement of the second flight said that the above-mentioned research was in addition to data gathered by the first, which was published July 7. That bulletin said the rocket's instruments had studied the ultraviolet part of the solar spectrum, and other matters.

6. Soviet Biological Experiments

(By Irwin Hersey [1])

In any broad discussion of man in space, neglect of the Soviet manned space flight program would be a glaring oversight. Questions as to the progress the Russians are making, where their program stands vis-a-vis our own, and when they will succeed in putting a man in space are, of course, difficult to answer, for almost the same reluctance to provide information is found in this area as in the field of Soviet rocket and missile technology.

Almost, but not quite—for, at the Third European Congress of Aviation Medicine at Louvain, Belgium, last September, a leading Soviet Physiologist, Andrei G. Kousnetzov, presented the first full-scale public rundown on Russian biological experimentation in this field. While the paper presented by Kousnetzov, who is chief of the physiology department of the Soviet Air Force Scientific Research Experimental Institute of Aviation Medicine in Moscow, was itself of great interest, the questions and answers which followed were even more enlightening.

In response to a series of questions by Col. John P. Stapp, chief of the USAF Aero Medical Laboratory, Dr. Kousnetzov revealed:

[1] In Astronautics, February 1959, p. 31 ff.

1. That no attempt had been made to catapult and parachute Laika from Sputnik II.

2. That there have been no Soviet rocket experiments involving human subjects "as far as is known."

3. That he had no personal knowledge of Soviet balloon experiments with human subjects or animals similar to the U.S. Manhigh project.

In response to a query by Capt. Neville P. Clark of the USAF Veterinary Corps regarding the time and cause of death of Laika, Dr. Kousnetzov explained that the experiment was programed to get information about the animal for 7 days, after which power gave out and telemetry data was no longer transmitted. From signals received earlier, he noted, Russian scientists learned that regeneration of air had stopped, leading to the conclusion that the animal had died from hypoxia or lack of oxygen. He did not say when this had occurred.

GAS COMPOSITION IN CAPSULE

A question by Captain Clark about cabin pressure and gas composition in the capsule used for the experiment brought a reply that the system used for oxygen regeneration maintained the composition of the gas "near the terrestrial one."

Dr. Kousnetzov began his paper by briefly reviewing the history of Soviet experimentation of this type, noting that investigations of the effect of space flight on human organisms have been going on since 1949. In the initial phase of the experiments, rockets flew encapsulated animals to heights of 100 to 210 kilometers (62 to 130 miles), and then ejected them for return to earth by parachute.

Animals were encapsulated in specially equipped, hermetically sealed cabins supplied with an air-conditioning system which permitted keeping gas composition of the air, temperature, and humidity at levels making possible normal activity of the organism under study. The air-conditioning system was designed for 2 days but needed to operate only the 3 hours during which animals were under observation.

Instrumentation provided data on the animals' breathing, blood pressure, biological electric currents, and temperature before launch, in rocket flight, and in parachuting back to earth, as well as changes in cabin pressure and temperature, and acceleration, he noted.

No major changes were observed in the animals that could be regarded as resulting from acceleration either on launching or when the parachute reached the dense air layers. The effect of 3 to 6 minutes of weightlessness was almost imperceptible. Animals sent aloft twice showed no perceptible changes in behavior or general condition either immediately after the flight nor any time thereafter.

The next phase of the experiments called for elimination of the capsule, catapult separation of an animal from the rocket during its descent and subsequent descent of the animal in a special high-altitude suit with the help of a parachute.

A good deal of attention was given to protecting the animals during the rocket's descent trajectory, when its flight was not fully stabilized. Two types of catapult experiments were carried out. In one, the catapult apparatus was started at a height of 75 to 85 kilometers (47 to 53 miles), with the parachute opening immediately and the animal's descent taking more than an hour. In the other, catapulting was effected at 39 to 46 kilometers (128,000 to 151,000 feet), the parachute opening at a height of only 4 kilometers (13,000 feet).

These experiments, too, proved successful, Dr. Kousnetzov noted, with neither catapult launching nor parachute descent detrimental to the animals' health or lives.

The third phase of the experiments began last year, culminating in animal rocket launchings to a height of 473 kilometers (294 miles). Animals also returned from these high-altitude flights in good health.

LAIKA EXPERIMENT

The rocket experiments permitted extensive study of various effects on living organisms in the upper air layers. However, Sputnik II, which carried Laika, made possible a biological experiment meeting all the conditions of space flight.

Of particular interest in the experiment was the state and behavior of Laika at the most crucial moments of flight—the period from launching to the time the satellite was placed in orbit. During this period, the animal was in such a position as to sustain transverse acceleration, and data about the condition and behavior of the animal were successfully transmitted and received for this period.

The data showed that the frequency of heart contractions rose to three times the initial frequency. Electrocardiogram analysis showed no serious changes in the workings of the heart, and later, despite the growing effect of acceleration, the frequency of heart contractions decreased. The animal's respiratory rate was also three to four times higher than the initial rate during this period.

The Soviet expert explained there was every reason to believe that changes noted in the animal's physiological functions were brought about by the sudden onset of external irritants—acceleration, noise, and vibration—which began at launching and continued until the satellite was orbiting.

A comparison of data from Sputnik II and from previous lab experiments led to the conclusion that Laika's condition had been satisfactory from launch to orbit.

The effect of the zero-gravity condition on the animal was also studied carefully. With the onset of weightlessness, Laika made small bounds on the floor because of contraction of the muscles of the limbs. The data indicated these movements were smooth and of short duration.

After a brief period, the rate of heart contractions fell, almost reaching the initial rate. However, it was observed that the period of time necessary to reach the original rate was about three times as long as in lab experiments in which Laika was subjected to the same acceleration as that of the satellite launching vehicle.

This, Dr. Kousnetzov explained, was probably due to the fact that, in lab experiments, the animal found itself in a normal condition after acceleration ceased, while in the sputnik, acceleration was followed by weightlessness. The absence of signals from receptive organs as to the position of the body in space, he believes, caused a change in the functional state of the nervous system regulating blood circulation and breathing, and led to delay in the return to normal of these functions. This phenomenon may have been aggravated as well by accompanying factors such as noise and vibration, their intensity being greater in the actual launching than in the lab experiments, he added.

Changes in the animal's physiological functions recorded during this period generally coincide with the results of the previous high-altitude rocket experiments. Dr. Kousnetzov commented.

Analysis of the electrocardiogram during the zero-gravity state showed some changes in the configuration of its elements and the duration of its intervals. These changes were in no way pathological, he pointed out, and were brought about by the increased functional load at the moment preceding the zero-gravity condition. The ECG showed alterations in the reflex and nervous character of the work of the heart. At a later stage, it showed a closer and closer resemblance to the ECG characterizing the animal's initial condition.

Despite the absence of gravity, Laika's motor movements were moderate. Return to normal of blood circulation and breathing during the zero-gravity state when the satellite was orbiting seems to indicate that weightlessness resulted in no major changes nor any stable changes in the animal's physiological functions, he noted. In other words, the animal got on satisfactorily both during the period when the satellite was going into orbit and when it was actually orbiting.

Finally, Dr. Kousnetzov stated that it was impossible to arrive at a final conclusion as to the effect of cosmic radiation on the animal since no direct indication of physiological influence was discovered.

However, he added, the results of the experiment must be regarded as encouraging for future research geared to protect the life and well-being of man in space.

U.S.S.R. RESEARCH AND DEVELOPMENT

While a good deal of this information had reached print long before the Louvain meeting, Dr. Kousnetzov's paper does represent one of the best rundowns on this subject available to date. What else the Russians are doing remains a secret hidden behind the Iron Curtain, but certainly some conclusions can be drawn.

In view of the fact that the Russians have already designed and built a workable space capsule which (apparently) has kept an animal alive in space for a considerable period of time; that animals have been sent on rocket flights (and successfully recovered) to altitudes considerably higher than those reached in similar U.S. experiments; and that Soviet scientists have indicated full awareness that the next great step in astronautics will consist of sending a man into space, there can be little doubt that the U.S.S.R. program is at least as far advanced as our own, and perhaps a little ahead.

Who wins the race is likely to be determined by how much effort goes into such programs in the next 12 to 18 months.

7. "Soviets View Man-in-Space Need," in Aviation Week, November 23, 1959, Page 27

Washington.—Soviet Union will place a man in space only when it encounters a task that automatic controls cannot perform, according to Soviet scientist A. A. Blagonravov, who says that thus far there is no need for manned space flight.

Blagonravov, a member of the presidium of the Soviet Academy of Sciences, told an American Rocket Society session he thinks manned space flight is technically feasible now, but that Russia will send a man into space only when it has some tasks for him to perform which cannot be performed by automatic instruments. He said that all present space tasks can be handled by automatic controls but that, when such systems cannot do the job, Soviet scientists will consider manned space flight.

Blagonravov termed reports of a training program for Russian astronauts, "ungrounded" and stemming mainly from journalistic imagination. He said Russia has no man-in-space program as such—just a program on research in flight safety. Blagonravov repreated earlier Soviet assertions that a man will be sent into space only when it is absolutely safe and when the reentry and recovery system is proved safe.

Blagonravov's denial of a specific man-in-space program at the ARS meeting clashes with earlier statements by Prof. Andrei Kuznetsov, head of the Soviet aerospace medical program. Kuznetsov told delegates to the 52d General Conference of the Federation Aeronautique Internationale in Moscow last summer that the Soviets have selected four astronauts for their first manned space capsule program (AW June 22, p. 79).

Russians also recently released pictures of Soviet "cosmonauts" in training (AW Oct. 26, p. 66).

Asked whether he thought the United States and Russia should use joint communication facilities for such projects as the United States Mercury program, Blagonravov said it is "very desirable" to discuss such a concept, but he observed that differences in equipment might raise some difficulties.

Five-man Russian delegation to the 14th annual ARS meeting was headed by Prof. Leonid I. Sedov, chairman of the Soviet Academy of Sciences' spaceflight commission and president of the International Astronautical Federation. Other members were Blagonravov; Prof. Valerian I. Krassovsky, chief of the upper-atmospheric physics department of the academy's Institute of Atmospheric Physics; Vitaly G. Kostomarov of the academy's foreign department, and Yuri S. Galkin, interpreter and secretary for the delegation.

Sedov, Blagonravov and Krassovsky presented detailed reports on Soviet space achievements. Krassovsky said further study is required to explain the "somewhat higher currents between the electrodes of an ion trap" founded in the vicinity of the moon by the second Soviet moon rocket. He said that, although no magnetic field stronger than 50 to 100 gammas was found near the moon, "fluctuations of the magnetic field" were registered in space between earth and the moon and "further investigations will reveal whether these fluctuations really exist and what characteristics they have. Moreover, if they reflect real values of the magnetic field, frozen into the interplanetary gas, then it is the first direct indication of the interplanetary magnetic field."

Sedov gave the point of impact of the second lunar rocket as about 500 miles north of the center of the visible lunar disk, south of the craters of Archimedes, Aristillus, and Autolycus. He said the flight of the third lunar rocket from earth to moon was at an inclination to the equatorial plane of 55° but that the moon's perturbation and subsequent perturbation by the earth produced a near-elliptic orbit inclined to the equator at about 80°. By the 10th revolution, the inclination is expected to be 48°, then increased to 57° on the 11th revolution—which now is expected to occur next March and be the last before the probe burns in the earth's atmosphere.

"This effect (of sun and moon), though unexpected at the first glance, depends only upon Newtonian forces," Sedov said. "It is evident that such effects should be taken into account during theoretical analysis of problems concerning the structure of planet systems and the properties of the orbits of different planes and their satellites in the solar system."

Russians showed a composite picture made from photographs taken by the third probe and said the photographing "must be continued," and must include shots with side illumination from the sun, which would cause surface characteristics to stand out more clearly.

Sedov was quoted last week in the Soviet newspaper Pravda as saying radio contact with the third probe was lost after its principal tasks were "fully accomplished," possibly "as a result of a collision with a meteorite."

Blagonravov said orientation of the third probe was controlled by two pairs of jets for turning it around the longitudinal axis and one pair for turning it around each diametrical axis.

8. "Moscow Doubted on Aims in Space—U.S. Officials Believe Soviet Plans To Launch a Man Despite Disavowals

(By John W. Finney)

[From the New York Times, November 26, 1959]

Washington, November 26.—American space officials believe that the Soviet Union has an active man-in-space program despite the denials by prominent Soviet space scientists.

Both nations, it is believed, have set their goals on placing man into space at the earliest possible time as a prelude to manned exploration of the moon and the solar system.

The Soviet man-in-space program, however, may differ from that of the United States in that it is being run by the military, rather than by civilian scientists.

Until recent weeks, there was no doubt in the minds of American space officials that the United States and the Soviet Union were in a race to achieve manned space flight.

WARNINGS TO PUBLIC

In fact, officials of the National Aeronautics and Space Administration, in an attempt to condition public opinion to another Soviet space triumph, were freely and publicly predicting that a Soviet astronaut would probably be first to orbit the earth in a space capsule.

But then a group of prominent Soviet space scientists arrived in the United States with the declaration that the Soviet Union had no man-in-space program as such, but rather only a general research program into the problems of space flight.

Prof. A. A. Blagonravov, a member of the presidium of the Soviet Academy of Sciences, told a meeting of the American Rocket Society that the Soviet Union would only attempt to place a man in space when absolute safety was assured and when there were tasks in space that could not be performed by automatic instruments.

Professor Blagonravov's comments mystified American space officials. The denial of a Soviet man-in-space program not only ran counter to the assumptions of Western officials but also clashed with stories that had emanated from the Soviet Union. Professor Blagonravov dismissed the stories as the result of journalistic imagination.

SELECTION OF MEN CITED

Last summer, for example, Prof. Andrei Kuznetsov, head of the Soviet space medical program, told delegates to the fifty-second general conference of the Fédération Aéronautique Internationale in Moscow that four men had been selected for space training. Then last month Ogonek, the Soviet magazine, carried an article and pictures of the "cosmonauts" in training.

In attempting to interpret the significance of the statements of Professor Blagonravov and his scientific colleagues, American space officials have come to two alternative conclusions.

One is that the Soviet scientists were playing dumb about the Soviet man-in-space program, either because of restrictions of Soviet secrecy or because of a deliberate attempt to lull the United States into false security.

The alternative is the one now generally held by space administration officials. It is that the civilian Soviet scientists are not involved in the man-in-space program, which is being managed by the military. In fact, it is believed the civilians have no great enthusiasm for putting a man into space at this point.

CIVILIANS NOTE SPENDING

In support of this latter alternative, space agency officials note that this lack of enthusiasm for manned space flight is shared by many scientists in this country. They feel that the money could be better spent for basic research with instrumented rockets and satellites.

American officials are still betting that the Soviet Union will be first to achieve a space flight around the earth. As Dr. T. Keith Glennan, head of the space agency, put it last week:

"I wish I could guarantee that we will beat the Russians to this accomplishment. I can't, of course, except to say that if hard work is going to do this job, we will succeed."

APPENDIX E

Biographies of Project Mercury Astronauts

Malcolm Scott Carpenter

Malcolm S. Carpenter, a lieutenant in the U.S. Navy, was born May 1, 1925, in Boulder, Colo. His mother is living in Boulder at 5335 Broadway. Carpenter's father, a retired chemist, lives in Palmer Lake, Colo. His wife is the former Rene Louise Price, whose parents, Mr. and Mrs. Lyle S. Price, live at 963 Ninth Street, Boulder. The Carpenters have four children: Mark Scott, 9; Robyn Jay, 7; Kristen Elaine, 3; and Candace Noxon, 2. Carpenter is 5 feet 10½ inches tall, weighs 160 pounds, and has green eyes and brown hair.

After receiving his early education through high school in Boulder, Carpenter entered Colorado College in 1943 to participate in the V–5 flight training program sponsored by the U.S. Navy. After a year there, he spent 6 months in training at St. Mary's preflight school, Moraga, Calif., and 4 months in primary flight training at Ottumwa, Iowa. When the V–5 program ended at the close of World War II, Carpenter entered the University of Colorado to major in aeronautical engineering. He received a degree there in 1949.

Following his graduation, Carpenter joined the Navy and received flight training from November 1949 to April 1951 at Pensacola, Fla., and Corpus Christi, Tex. He spent 3 months in the Fleet Airborne Electronics Training School San Diego, Calif., and, until October 1951 in a Lockheed P–2V transitional training unit at Whidbey Island, Wash.

In November 1951 he was assigned to Patrol Squadron 6 based at Barbers Point, T.H. During the Korean conflict, he was engaged with Patrol Squadron 6 in antisubmarine patrol, shipping surveillance and aerial mining activities in the Yellow Sea, South China Sea and the Formosa Straits. In 1954 he entered the Navy Test Pilot School at the Naval Air Test Center, Patuxent River, Md., and after completion of his training, was assigned to the electronics test division of the NATC. In this assignment Carpenter conducted flight test projects with the A–3D, F–11F and F–9F and assisted in other flight test programs. He then attended the Navy's General Line School at Monterey, Calif., for 10 months and the Naval Air Intelligence School, Washington, D.C., for a further 8 months. In August 1958 he was assigned to the U.S.S. *Hornet*, antisubmarine aircraft carrier, as air intelligence officer. He has accumulated more than 2,800 flying hours, including 300 in jet aircraft.

His hobbies include skin diving, archery and water skiing.

Leroy Gordon Cooper, Jr.

Leroy G. Cooper, Jr., a captain in the U.S. Air Force, was born March 6, 1927, in Shawnee, Okla. He is 5 feet 9½ inches tall and weighs 150 pounds. The 32-year-old astronaut has blue eyes and brown hair. He considers as his hometown Carbondale, Colo., where his parents, Col. and Mrs. Leroy G. Cooper, have a ranch. Colonel Cooper is retired from the Air Force. His wife is the former Trudy Olson of Seattle, Wash. The couple has two daughters, Camala K., 10, and Janita L., 9.

Cooper attended primary and secondary schools in Shawnee, and he attended the University of Hawaii 3 years. He received a degree in aeronautical engineering through the Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio, in August 1956.

Cooper entered the Marine Corps in 1945 after his graduation from high school. He attended the Naval Academy Preparatory School and was a member of the Presidential honor guard in Washington immediately before his discharge in August 1946. While at the University of Hawaii, he received a commission in the Army. He transferred this commission to the Air Force and was recalled by that service for extended active duty in 1949 for flight training. After his training, he was assigned to the 86th Fighter Bomber Group in Munich, Germany, as an F–84, and later, an F–86 pilot. After his graduation from AFIT, he was assigned to the Air Force Experimental Flight Test School at Edwards Air Force

Base, Calif. He was graduated from this school in April 1957 and was assigned duty in the Performance Engineering Branch of the Flight Test Division at Edwards. He conducted flight test on experimental fighter aircraft. Cooper has 2,300 flying hours, including 1,400 in jets.

His hobbies are photography, riding, hunting and fishing.

John Herschel Glenn, Jr.

John H. Glenn, Jr., a lieutenant colonel in the U.S. Marine Corps, was born July 18, 1921, in Cambridge, Ohio. He considers New Concord, Ohio, his permanent home. He attended primary and high schools in New Concord, and Muskingum College. His parents are Mr. and Mrs. John H. Glenn. The elder Glenn is a retired operator of a plumbing and heating business. Mrs. Glenn is the former Anna Margaret Castor, daughter of Dr. and Mrs. H. W. Castor. The elder Glenns and Castors all live on Bloomfield Road in New Concord. The Glenns have two children: John David, 13, and Carolyn Ann, 12. Glenn also has a sister, Mrs. Jean Pinston, of Cambridge. He is 5 feet 10½ inches tall, weighs 180 pounds and has green eyes and red hair.

Glenn entered the naval aviation cadet program in March 1942. He was graduated and commissioned in the Marine Corps a year later. After advanced training, he joined Marine Fighter Squadron 155 and spent a year flying F-4U fighters in the Marshall Islands. During his World War II service, he flew 59 combat missions. After the war, he was a member of Fighter Squadron 218 on North China patrol and had duty in Guam. From June 1948 to December 1950, he was an instructor in advance training at Corpus Christi, Tex. Glenn then attended Amphibious Warfare School at Quantico, Va. In Korea, he flew 63 missions with Marine Fighter Squadron 311 and 27 while an exchange pilot with the Air Force. In the last 9 days of fighting in Korea, he downed three MIG's in combat along the Yalu River. After Korea, Glenn attended test pilot school at the Naval Air Test Center, Patuxent River, Md. After graduation, he was project officer on a number of aircraft, including the F-8U, F-8U-1, and F-8U-P. In November 1956 he was assigned to the Fighter Design Branch of the Navy Bureau of Aeronautics in Washington.

Glenn has been awarded the Distinguished Flying Cross on 5 occasions and he holds the Air Medal with 18 clusters for his service during World War II and Korea. In July 1957 while project officer of the F-8U, he set a transcontinental speed record from Los Angeles to New York, spanning the country in 3 hours 23 minutes. He has more than 5,000 hours of flying time, including 1,500 hours in jet aircraft. Glenn attended the University of Maryland during his Washington assignment.

The Glenn family hobbies are boating and water skiing.

Virgil Ivan Grissom

Virgil I. Grissom, a captain in the U.S. Air Force, was born April 3, 1926, in Mitchell, Ind. Five feet, seven inches tall, he weighs 155 pounds and has brown eyes and brown hair. His parents, Mr. and Mrs. Dennis D. Grissom, live at 715 Baker Street, Mitchell. He has two brothers, Norman, of Mitchell, and Lowell, a sophomore at Indiana University, and a sister, Mrs. Joe Beavers of Baltimore. Mrs. Grissom is the former Betty L. Moore. Her father, Claude Moore, lives in Mitchell. Her mother is deceased. The Grissoms have two sons, Scott, 9, and Mark, 5.

Grissom attended primary and high schools in Mitchell and was graduated from Purdue University with a degree in mechanical engineering in 1950.

He first entered the Air Force in 1944 as an aviation cadet. He was discharged in November 1945. He returned to aviation cadet training after his graduation from Purdue, and he received his wings in March 1951. Grissom joined the 75th Fighter-Interceptor Squadron at Presque Isle, Maine, as an F-86 fighter pilot. He flew 100 combat missions in Korea in F-86's with the 334th Fighter-Interceptor Squadron. He left Korea in June 1952 and became a pilot instructor at Bryan, Tex. In August 1955 he went to the Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio, to study aeronautical engineering. In October 1956 he attended test pilot school at Edwards Air Force Base, Calif., and returned to Wright-Patterson Air Force Base in May 1957 as a test pilot assigned to the Fighter Branch. He has flown more than 3,000 hours, over 2,000 in jets.

Grissom has been awarded the Distinguished Flying Cross and Air Medal with cluster.

His hobbies are hunting and fishing.

Walter Marty Schirra, Jr.

Walter M. Schirra (Shi-RAH), Jr., a lieutenant commander in the U.S. Navy, was born March 12, 1923, in Hackensack, N.J. The 36-year-old astronaut is 5 feet 10 inches tall, weighs 185 pounds, and has brown hair and brown eyes. His parents, Mr. and Mrs. Walter M. Schirra, reside in Honolulu, T.H., where the elder Schirra is a civil engineer with the Air Force. The senior Schirra was a World War I ace in the Army Air Corps. After the war, he and his wife barnstormed throughout the Eastern United States in a light plane. The astronaut's wife is the former Josephine C. Fraser of Seattle, Wash. The couple has two children: Walter III, 8, and Suzanne Karen, 1. Mrs. Schirra is the daughter of Mrs. James L. Holloway, wife of Admiral Holloway, who was commander in chief of the Northeastern Atlantic and Mediterranean area. Schirra also has a sister, Mrs. John H. Burhans, who lives in Patuxent River, Md.

Schirra attended primary and junior high schools in Oradell, N.J. He was graduated from Dwight Morrow High School, Englewood, N.J., in 1940, and attended Newark (N.J.) College of Engineering 1 year. He was graduated from the U.S. Naval Academy in 1945.

Schirra has had service on board the battle cruiser *Alaska*, the staff of the 7th Fleet, flight training at Pensacola, in a Navy fighter squadron (71), and as an exchange pilot with the 154th U.S. Air Force Fighter Bomber Squadron. He went with this squadron to Korea where he flew 90 combat missions in F–84E aircraft. He downed one MIG and has one probable MIG. He took part in development of the Sidewinder missile at China Lake, Calif. He was project pilot for the F–7U–3 Cutlass and instructor pilot for the Cutlass and F–J3 Fury. He flew F–3H–2N Demons as operations officer of Fighter Squadron 124 on board the carrier *Lexington* in the Pacific. He then attended Naval Air Safety Officer School at the University of Southern California, and test pilot training at the Naval Air Test Center, Patuxent, Md. His last assignment was at Patuxent in suitability development work on the F–4H. He has 3,000 hours of flying time, 1,700 hours in jets.

He has been awarded the Distinguished Flying Cross and two Air Medals for his Korean service.

Alan Bartlett Shepard, Jr.

Alan B. Shepard, Jr., a lieutenant commander in the U.S. Navy, was born November 18, 1923, in East Derry, N.H. The 35-year-old astronaut is 5 feet 11 inches tall, weighs 160 pounds and has blue eyes and brown hair. His parents Col. and Mrs. Alan B. Shepard, live in East Derry where the elder Shepard, a retired Army of the United States officer, is an insurance broker. Shepard is married to the former Louise Brewer of Kennett Square, Pa. The couple has two daughters, Juliana, 8, and Laura, 12. Shepard's sister, Mrs. Pauline S. Sherman, resides in Montclair, N.J.

Shepard attended primary school in East Derry and was graduated from Pinkerton School, Derry, N.H., in 1940. He studied 1 year at Admiral Farragut Academy, Toms River, N.J., and then entered the Naval Academy, Annapolis. He was graduated from Annapolis in 1944. He was graduated from the Naval War College, Newport, R.I., in 1958.

The astronaut saw service on the destroyer *Cosgrove*, in the Pacific during World War II. He then entered flying training at Corpus Christi, Tex., and Pensacola, Fla. He received his wings in March 1947. Subsequent service was in Fighter Squadron 42 at the Norfolk Naval Air Station and Jacksonville, Fla. He also spent several tours in the Mediterranean. Shepard went to test pilot school at Patuxent River, Md., and served two tours in flight test there. During this service, he took part in high altitude tests to obtain data on light at different altitudes and in a variety of air masses over the North American Continent. He also took part in experiments in test and development of the Navy's in-flight refueling system; carrier suitability trials of the F–2H3 Banshee, and Navy trials of the first angled carrier deck. Between his flight test tours at Patuxent, Shepard was assigned to Fighter Squadron 193 at Moffett Field, Calif., a night fighter unit flying Banshee jets. He was operations officer of this squadron and made two tours with it to the Western Pacific on board the carrier *Oriskany*. He has been engaged in the test of the F–3H Demon, F–8U Crusader, F–4D Skyray and F–11F Tigercat. He was project test pilot on the F–5D Skylancer. The last 5 months at Patuxent were spent as an instructor in the test pilot school. After his graduation from the Naval War College, Shepard joined the staff of the commander in chief, Atlantic Fleet, as aircraft readiness officer. He has 3,600 hours of flying time, 1,700 in jets.

Shepard's hobbies are golf, ice skating and water skiing.

Donald Kent Slayton

Donald K. Slayton, a captain in the U.S. Air Force, was born March 1, 1924, in Sparta, Wis. The 35-year-old astronaut is 5 feet 10½ inches tall, weighs 160 pounds and has blue eyes and brown hair. His parents, Mr. and Mrs. Charles S. Slayton, live in Sparta. A brother, Howard, and sister, Mrs. Lyndahel Hagen, also live in Sparta. Slayton's immediate family also includes a brother Richard, of San Jose, Calif.; another brother, Elwood, and two sisters, Mrs. Milton Madsen and Mrs. Harold Schluenz, all of Madison. His wife is the former Marjorie Lunney, daughter of Mr. and Mrs. George Lunney of Los Angeles, Calif. The Slaytons have one son Kent, 2.

Slayton attended primary and high schools in Sparta, graduating from Sparta High School in 1942. He entered the University of Minnesota in January 1947 and was graduated with a degree in aeronautical engineering in August 1949.

He entered the Air Force as an aviation cadet in 1942 and after instruction at Vernon, Tex., and Williams, Ariz., won his wings in April 1943. He flew 56 combat missions in B–25's in Europe with the 340th Bombardment Group (Medium). In mid-1944, he returned to this country as a B–25 instructor pilot at Columbia, S.C., and then served with a unit checking out pilots in the A–26. He joined the 319th Bombardment Group (Medium) and went to Okinawa in April 1945 where he flew seven combat missions over Japan. He was an instructor pilot in B–25 aircraft for about a year after the war. Following his graduation from the University of Minnesota, he was an aeronautical engineer with Boeing Aircraft Co. in Seattle, Wash., until recalled in early 1951 to active duty with the Air National Guard, in which he maintained membership during his student days at the University of Minnesota. On his recall, he was assigned to Minneapolis as maintenance flight test officer of an F–51 squadron. He then spent a year and one-half at 12th Air Force Headquarters as technical inspector, and a like period as fighter pilot and maintenance officer with the 36th Fighter Day Wing in Bitburg, Germany. He returned to the United States in June of 1955 and attended the Air Force Flight Test Pilot School at Edwards Air Force Base, Calif. In January 1956 he became an experimental test pilot at Edwards, where he has flown all jet fighter type aircraft built for the Air Force. His last assignment was chief of Fighter Section A. He has 3,400 flying hours, 2,000 in jets.

Slayton holds the Air Medal with cluster.

His hobbies are hunting, fishing, shooting, archery, photography, and skiing.

APPENDIX F

Chronology of Satellites, Lunar Probes and Space Probes

1. *United States and Russian satellites, lunar probes and space probes, 1957, 1958, and 1959*

(Official statistics prepared by the National Aeronautics and Space Administration [1])

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Perigee[2] (miles)	Apogee[2] (miles)
Sputnik I, Russia: Satellite (sphere). Estimate of total payload weight in orbit: About 4 tons (unofficial). Scientific instrumentation in payload: 184 lbs.	Oct. 4, 1957–Jan 4, 1958.	Not disclosed	Dimensions: 22.8 in. in diameter. Experiments: Internal temperatures, pressures, and other data. Shell composition: aluminum alloys. Antennas: 4 spring-loaded whip antennas, 4 ft. 10.5 in. to 9 ft. 6 in. Transmitters: (*a*) 20.005 mc.; (*b*) 40.002 mc. Power supply: Chemical batteries. Transmitter lifetime: (*a*) and (*b*) stopped Oct. 27, 1957.	Period: 96.17 minutes; speed (perigee): 18,000 m.p.h.; speed (apogee): 16,200 m.p.h. Inclination to Equator: 65°.	142	588
Sputnik II, Russia: Satellite (complex). Estimate of total payload weight in orbit: About 4 tons (unofficial). Scientific instrumentation in payload: 1,120 lbs.	Nov. 3, 1957–Apr. 14, 1958.	do	Dimensions: Not disclosed. Experiments: Cosmic rays: solar ultraviolet and X-radiation; test animal "Laika" (dog); temperatures; pressures. Shell composition: Aluminum alloys. Antennas: Not disclosed. Transmitters: (*a*) 20.005 mc.; (*b*) 40.002 mc. Power supply: Chemical batteries. Transmitter lifetime: (*a*) and (*b*) stopped Nov. 10, 1957.	The available acceleration of this satellite led to the discovery of significant solar influence on upper atmosphere densities. Period: 103.70 minutes; speed (perigee): 18,000 m.p.h.; speed (apogee): 15,000 m.p.h. Inclination to Equator: 65°.	140	1,038
Vanguard (test vehicle 3) United States: Satellite (sphere). Scientific payload and total weight in flight: 3.25 lbs.	Dec. 6, 1957–0	U.S. Navy test vehicle 3. Stages: 3—1st: liquid: 2d: liquid; 3d: solid. Gross takeoff weight: 22,600 lbs. Height: 72 ft. Diameter (base): 45 in.	Dimensions: 6 in. in diameter. Experiments: Micrometeor impact and geodetic measurements. Shell composition: Magnesium, aluminum, silicon monoxide. Antennas: 1 turnstile antenna; 1 dipole antenna with total of 6 12-in. rod elements. Transmitters: (*a*) 108 mc. at 10 mw.; (*b*) 108.03 mc. at 5 mw. Power supply: (*a*) mercury batteries; (*b*) 6 groups of solar converters.	Vehicle lost thrust after 2 seconds and was consumed in flames. Cause: malfunction in 1st stage.	0	0
Explorer I, United States: Satellite (cylinder). Total payload weight in orbit, 30.8 lbs. Scientific instrumentation in payload, 18.13 lbs.	Jan. 31, 1958 (estimated lifetime: 3 to 5 yr.).	U.S. Army Jupiter-C: Stages: 4—1st, elongated Redstone (liquid); 2d, scaled-down Sergeant rockets (solid); 3d, scaled-down Sergeant rockets (solid); 4th, single scaled-down Sergeant (solid). Height: 68.6 ft.	Dimensions: 80 in. long; 6 in. in diameter. Experiments: cosmic rays; micrometeorites: (*a*) microphone; (*b*) gages; temperatures: internal, rear skin, front skin, and nose cone. Shell composition: Steel with 8 aluminum oxide strips. Antennas; 1 turnstile antenna with 4 whip elements each 22.5 in. long; 1 dipole antenna using skin of satellite itself. Transmitters: (*a*) 108 mc. at 10 mw. and (*b*) 108.03 mc. at 60 mw. Power supply: Mercury batteries. Transmitter lifetime: (*a*) Stopped May 23, 1958; (*b*) stopped Feb. 11, 1958; began again Feb. 24; stopped finally Feb. 28, 1958.	Explorer I is credited with what is probably the most important satellite discovery of the International Geophysical Year; i.e., a radiation belt around the Earth identified by Dr. James A. Van Allen, head of the University of Iowa Physics Department. A 2d belt was discovered later by Pioneer III. Period: 114.8 min. Inclination to Equator 33.34°.	224	1,573

Vanguard: (test vehicle 3 backup) United States: same as TV 3.	Feb. 5, 1958–0	Same as Vanguard test vehicle 3.	Same as Vanguard test vehicle 3	After a successful liftoff and 57 sec. of flight, a connection between units of 1st stage control system failed to function. At an altitude of 20,000 ft., the rocket veered off course with such force that it snapped apart and fell.	0	0
Explorer II, United States: Satellite (cylinder). Total payload weight in orbit, 31.50 lbs. Scientific instrumentation payload, 18.83 lbs.	Mar. 5, 1958–0	U.S. Army Jupiter-C (same as Explorer-I).	Dimensions: 80 in. long; 6 in. in diameter. Experiments: Cosmic ray count; micrometeor impact count; cosmic ray measurement. Shell composition: No. 410 stainless steel. Antennas: 2 dipole antennas using skin of satellite itself. Transmitters: (a) 108.03 mc. at 60 mw.: (b) 108.00 mc. at 10 mw. Power supply: Mercury batteries.	Last stage failed to ignite. Vehicle did not achieve orbit. Flight time: 823 sec.	0	0
Vanguard I, United States: Satellite (sphere). Scientific payload and total weight in orbit, 3.25 lbs. (Also in orbit, 50-lb. 3d stage rocket casing.)	Mar. 17, 1958 (estimated 200 yrs.–1,000 yrs.).	Same as test vehicle 3	Dimensions: 6.4 in. in diameter. Experiments: Temperatures and geodetic measurements. Shell composition: Aluminum. Antennas: one turnstile antenna and one dipole antenna with total of six 12-in. rod elements. Transmitters: (a) 108 mc. at 10 mw.; (b) 108.03 mc. at 5 mw. Power supply: (a) Mercury batteries; (b) 6 groups of solar converters. Transmitter lifetime: (a) Ceased operating Apr. 5, 1958; (b) will operate indefinitely.	The solar-powered radio should transmit indefinitely. The Army Map Service has been making electronic observations of the satellite from Pacific islands to pinpoint their location more exactly. The satellite is also being used for more exact determination of the Earth's shape.	409	2,453
Explorer III, United States: Satellite (cylinder). Total payload weight in orbit, 31 lbs. Scientific instrumentation payload, 18.56 lbs.	Mar. 26, 1958 (June 27, 1958).	U.S. Army Jupiter-C (same as Explorers I and II).	Dimensions: 80 in. long; 6 in. in diameter. Experiments: Cosmic rays with tape-recorder feature; micrometero gages; temperatures, (a) skin and (b) internal. Shell composition: Steel with 8 aluminum oxide strips. Antennas: 2 dipole antennas using skin of satellite itself. Transmitters: (a) 108 mc. at 10 mw.; (b) 108.03 mc. at 60 mw. Power supply: Mercury batteries. Transmitter lifetime: (a) Telemetering and beacon signal stopped May 10, 1958; beacon transmitted again May 15–June 16; (b) first stopped May 14; responded erratically May 22–June 5, 1958.	Explorer yielded valuable data on the radiation belt discovered by Explorer I as well as data on micrometeor impacts (density of cosmic dust) and internal and external temperature of the satellite. Period: 115.87 min. Inclination: 33.4°.	121	1,746
Vanguard (test vehicle 5): Satellite (sphere). Scientific payload and total weight in orbit, 21.5 lbs.	Apr. 28, 1958–0	Same as TV 3	Dimensions: 20 in. in diameter. Experiments: Measure X-radiation from the sun and environmental measurements. Shell composition: Highly polished silicon-monoxide-coated magnesium. Antennas: 4 metal rods. Transmitters: 108 mc, at 80 mw, tracking and telemetry. Power supply: Mercury batteries.	2 minor components (electric relays) malfunctioned and failed to signal the 3d stage to fire. 2d and 3d stages impacted 1,500 miles from launch site.	0	0

See footnotes at end of table.

1. United States and Russian satellites, lunar probes and space probes, 1957, 1958, and 1959—Continued

(Official statistics prepared by the National Aeronautics and Space Administration [1])

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Perigee[2] (miles)	Apogee[2] (miles)
Sputnik III, Russia: Satellite (conical). Total payload weight in orbit: About 7,000 lbs. (unofficial). Scientific instrumentation payload, 2,925 lbs.	May 15, 1958; estimated lifetime: 15 months.	Not disclosed	Dimensions: 11 ft., 9 in. long; 5 ft. 8 in. wide at base. Experiments: Atmospheric pressure and composition; concentration of positive ions; satellite's electrical charge and tension of earth electrostatic field; tension of earth's magnetic field; intensity of sun's corpuscular radiation; composition and variations of primary cosmic radiation; disribution of photons and heavy nuclei in cosmic rays; micrometeors; temperature measurements. Shell composition: Aluminum alloys. Antennas: Folded dipole antennas and trailing rod antennas. Transmitters: (*a*) 20.005 mc. (transmission at 40.01 mc. is harmonic of 1st) Power supply: (*a*) chemical batteries; (*b*) solar batteries.	Period: 106 min.; speed (perigee): 18,837; speed (apogee): 14,637. Inclination to Equator: 65.3°.	135	1,167
Vanguard, satellite launching vehicle 1 (no name), United States: Satellite (sphere). Scientific payload and total weight in orbit: 21.5 lbs.	May 27, 1958–60.	Same as TV 3	Dimensions: 20 in. in diameter. Experiments: Solar Lyman-Alpha radiation and space environment. Shell composition: Highly polished silicon monoxide coated magnesium sphere. Antennas: 4 metal rods. Transmitter: (*a*) 108 mc. at 80 mw., tracking and telemetry. Power supply: Mercury batteries. Transmitter lifetime: same as flight time; i.e., 20 min.	Second stage engine did not cut off properly, causing vehicle to fly with nose upward rather than parallel to earth. Caused 3d stage to fly in high arc-like trajectory. 3d stage of vehicle reached peak altitude of 2,200 miles and traveled 7,500 miles from Cape Canaveral, landing near east coast of Union of South Africa. Flight time: 20 min.	0	0
Vanguard (SLV 2) (no name) United States: Satellite (sphere). Scientific instrumentation in payload and total weight in orbit: 21.5 lbs.	June 26, 1958–60.	do	Dimensions: 20 in. in diameter. Experiments: Measurements of X-radiation from the sun and environmental measurements. Shell composition: Highly polished silicon monoxide magnesium sphere. Antennas: 4 metal rods. Transmitters: 108 mc. at 80 mw, tracking and telemetry. Power supply: Mercury batteries.	Second stage motor cut off prematurely due to low chamber pressure and terminated the flight.	0	0
Explorer IV, United States: Satellite (cylinder). Total payload weight in orbit: 38.4 lbs. Scientific instrumentation in payload: 25.8 lbs.	July 26, 1958–Oct. 22, 1959.	Same as Explorer I	Dimensions: 80.39 in. long; 6.25 in. in diameter. Experiments: 2 Geiger-Mueller counters and 2 scintillation counters to measure corpuscular radiation at several intensity levels. The subcarrier oscillator was calibrated to give internal temperature measurements. Shell composition: stainless steel. Antennas: 2 dipole antennas using the skin of the satellite itself. Transmitters: (*a*) 108 mc. at 10 mw.; (*b*) 108.03 mc. at 24 mw. (each transmitter broadcasts all 5 channels of information simultaneously and con-	Same as Explorer I and III, i.e. valuable data on radiation belts, etc. Period: 110.27 minutes. Inclination to Equator: 50.29°.	163	1,380

			tinuously. The 1st transmitter is primarily for tracking.) Power supply: Mercury batteries. Transmitters lifetime: Sept. 3, 1958: Telemetry on channels 2 and 5 cease. Sept. 9, 1958: 108.00 mc. transmitter ceased operation Sept. 19, 1958: Last intelligible telemetry on 108.03 mc. transmitters. Oct. 6, 1958: 108.03 mc. transmitter ceased.			
No name, United States: Lunar probe (toroidal). Total payload weight in flight, including 4th stage shell: 83.8 lbs. Scientific instrumentation in payload: 25 lbs.	Aug. 17, 1958-0..	Thor-Able I Stages: 4. 1st: Thor (liquid); 2d: Modified Vanguard. 2d stage (liquid); 3d: X2 Allegany Ballistic Laboratory (solid); 4th: Thiokol (solid). Gross take-off weight: 112,000 lbs.; height: 88.1 ft.	Dimensions: 29 in. in diameter; 30 in. long. Experiments: Measurements of radiation in space; magnetic fields of Earth and Moon; density of micrometeoric matter; internal temperatures; electronic scanner. Shell composition: Fiberglass. Antennas: Two 12-inch whips. Transmitters: (a) 108.6 mc. at 300 mw. (telemetry and doppler command); (b) 108.09 mc. at 1 watt. Power supply: Mercury batteries. Transmitter lifetime: 10 days.	Engine failure in 1st stage caused vehicle blow up 77 seconds after launch.	[3]	[3]
Explorer V, United States: Satellite (cylinder). Total payload weight in orbit: 38.43 lbs. Scientific instrumentation in payload: 25.8 lbs.	Aug. 24, 1958-0..	Jupiter-C	Dimensions: 80 in. long, 6 in. in diameter. Experiments: measurement of corpuscular radiation at several intensity levels. Shell composition: No. 410 stainless steel. Antennas: 2 dipole antennas using skin of satellite itself. Transmitters: (a) 108.03 mc. at 30 mw.; (b) 108.00 mc. at 10 mw. Power supply: Mercury batteries.	Successful launching. All stages fired. Orbit was not achieved because of a collision between parts of the booster and the instrument compartment which carried the 3 high-speed stages. The high-speed stages fired in wrong direction. Flight time: 659 seconds.	0	0
Vanguard (SLV 3) United States: Satellite (sphere). Scientific instrumentation in payload and total weight, 21.5 lbs.	Sept. 26, 1958-0..	Same as TV 3	Dimensions: 20 in. in diameter. Experiments: 2 infrared photocells to scan earth's cloud cover. Shell composition: Magnesium. Antennas: 1 turnstile antenna with 4 30-in. spring-loaded rod elements. Transmitters: 108.00 mc. at 10 mw. and 108.03 mc. at 1 watt. Power supply: Mercury batteries.	2d stage failed to give minimal performance, which caused vehicle to fall back into atmosphere and burn up. It is believed to have made 1 complete orbit of Earth before falling back and burning up over central Africa.	0	0
Pioneer I, United States: Lunar probe (torodial). Total weight in flight, 84.4 lbs., including 43.7 lbs. of verniers and retrorockets. Scientific instrumentation in payload, 39 lbs.	Oct. 11-12, 1958, or 43 hrs. 17½ min.	Thor-Able I	Dimensions: 29 in. in diameter, 30 in. long. Experiments: Measurements of radiation in space; magnetic fields of Earth and Moon; density of micrometeor matter; internal temperatures; electronic scanner. Shell composition: Fiberglas. Antennas: 2 12-in. whips. Transmitter: (a) 108.06 mc. at 300 mw. (telemetry and Doppler command); (b) 108.06 mc. at 1 watt (controls). Power supply: Mercury batteries. Transmitter lifetime: 10 days.	Reentered atmosphere over South Pacific Oct. 12, 1958. (a) Determination of radial extent of radiation band. First observation that radiation is a band. (b) Mapped total ionizing flux. (c) 1st observation of hydromagnetic oscillations of magnetic field of Earth. (d) Discovered departure of magnetic field from theoretical prediction. (e) 1st determination of the density of micrometeors in interplanetary space. (f) 1st measurements of the interplanetary magnetic field.	[4]	[4]

See footnotes at end of table.

1. United States and Russian satellites, lunar probes and space probes, 1957, 1958, and 1959—Continued

(Official statistics prepared by the National Aeronautics and Space Administration [1])

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Perigee[2] (miles)	Apogee[2] (miles)
Beacon, United States: Inflatable satellite (sphere). Payload case, 18.3 lbs.; rocket case, 11.27 lbs.; total, 31.5 lbs. Weight of inflatable satellite when free of payload case, 9.26 lbs.	Oct. 23, 1958-0	Jupiter-C	Dimensions: 50 in. long, 7 in. in diameter; contained the foiled sphere, tracking transmitter, kick motor, and pressurized bottle. Experiments: Ejection of sphere from payload package; sphere itself would be used to study atmospheric density at various levels during lifetime of about 2 weeks. Shell composition: Mylar polyester film and microthin aluminum foil. Transmitters: None.	Part of the cluster, including payload, separated from the booster prior to booster burnout. Flight time of payload, 424 sec. Flight time of booster, 526 sec.	0	0
Pioneer II, United States: Lunar probe (toroidal). Total weight in flight, 86.4 lbs. Scientific payload, 34.3 lbs.	Nov. 8, 1958, 42.4 min.	Thor-Able I	Dimensions: 29 in. in diameter; 30 in. long. Experiments: Total ionizing radiation; cosmic ray flux; magnetic fields of Earth and Moon; density of micrometeoric matter; internal temperatures; electronic scanner. Shell composition: Fiberglas. Antennas: 2 12-in. whips. Transmitters: 108.06 mc. at 300 mw. (telemetry and Doppler command) and 108.09 mc. at 100 mw. (telemetry). Power supply: Mercury batteries. Transmitter lifetime: 10 days.	3d stage failed to ignite. Reentered atmosphere 28.7° N., 1.9° E. (*a*) Evidence that equatorial region about Earth has higher flux and higher energy radiation than previously considered. (*b*) Suggestion that micrometeor density is higher around Earth than in space.	(5)	(5)
Pioneer III, United States: Space probe (conical). Total weight in flight and scientific payload, 12.95 lbs.	Dec. 6-7, 1958, or 38 hr., 6 min. after launch.	Juno II stages (4): 1st, Jupiter (liquid); 2d, 11 clustered Sergeants (solid); 3d, 3 clustered Sergeants (solid). Gross take-off weight, 121,000 lbs.	Dimensions: 23 in. long; 10 in. maximum diameter. Experiments: Measurement of radiation in space. Shell composition: Gold-washed Fiberglas. Antenna: Cone itself serves as antenna; gold is conductor. Transmitters: 960.05 mc. at 180 mw. Power supply: Mercury batteries. Transmitter lifetime: 90 hr.	Discovered 2d radiation belt around Earth. Reentered atmosphere over French Equatorial Africa on Dec. 7, 1958. Designed velocity, 24,897 m.p.h. Attained velocity, about 24,000 m.p.h.	(6)	(6)
Project Score (Atlas), United States: Satellite. Total weight in orbit, 8,750 lbs. Scientific instrumentation in payload, 150 lbs.	Dec. 18, 1958-Jan. 21, 1959.	WS107A-1 (Atlas): Powerplant, 2 boosters (approximately 150,000 lbs. each) and 1 sustainer engine (all liquid) plus 2 verniers. Gross take-off weight, about 244,000 lbs.; height, 85 ft.; diameter, 10 ft.	Dimensions: 85 ft. long, 10 ft. in diameter. Experiments: Twin packages of radio-transmitting, recording, and receiving apparatus, each weighing 35 lbs. Other components included a battery, a voltage converter, radio beacon, and a control unit. Shell composition: Stainless steel. Antennas: Slot-type, flush with body of the Atlas. Transmitters: FM, 132,435 mc. and 132,905 mc. Minitrack signals: 107.97 mc. and 107.94 mc. Power supply: Mercury batteries. Transmitter lifetime: 12 days.	1st time a human voice has been beamed from outer space. Message from President Eisenhower recorded and transmitted Satellite accepted and relayed messages from ground stations in Texas, Arizona, and Georgia. It came down in vicinity of Midway Island in Pacific Ocean. initial period, 101.46 min. Inclination, 32.3°.	110	920

Lunik or Mechta (Dream), Russia: Space probe (sphere). Total weight in flight, 3,245 lbs.[7] Instrumentation weight, 796 lbs.	Jan. 2, 1959 (believed to be in orbit around sun).	T-3 stages: 3. Speculated total thrusts, 580,000 lbs. Height, 110 ft.	Dimensions: Not disclosed. Experiments: Instruments to measure temperature and pressure inside vehicle; instruments to study gas components of interplanetary matter and corpuscular radiation of the sun; magnetic fields of earth moon; meteoric particles in space; heavy nuclei in primary cosmic radiation and other properties of cosmic rays. Shell composition: Pentagonal strips of stainless steel made of 2 hermetically sealed shells of aluminum-magnesium alloy. Antennas: Not disclosed. Transmitters: 3. (a) 19.997 mc. and 19.995 mc. signals of 1.6-sec. duration; (b) 19.993 mc. signals of 50.9 sec. duration; (c) 183.6 mc.	In orbit around sun on 15-mo. cycle.	--------	--------
Vanguard II, United States: (Sphere). Total weight in orbit and scientific instrumentation, 20.74 lbs.	Feb. 17, 1959. Expected lifetime, 10 yrs. or more.	Vanguard rocket (same as test vehicle 3).	Dimensions: 20 in. in diameter. Experiments: Cloud cover. Shell composition: Highly polished silicon monoxide coated magnesium. Antennas: 4 metal rods. Transmitters: (a) 108 mc. at 10 mw.; (b) 108.03 mc. at 80 mw. triggered from ground. Power supply: Mercury batteries. Transmitter lifetime: (a) 23 days; (b) 27 days. Satellite contained 2 photocells designed to produce crude images of cloud cover for 2-week period.	Period: 125.85 min. Inclination to Equator: 32.88°. In general the satellite and its instrumentation functioned as planned. However, interpretation of data has been difficult because satellite developed a wobbling (precessing) motion.	347	2,064
Pioneer IV, United States: (Conical). Total weight in flight and scientific instrumentation, 13.40 lbs.	Mar. 3, 1959. In orbit around sun.	Juno II (same as Pioneer III).	Dimensions: 20 in. long; 9 in. in diameter. Experiments: Measurement of radiation in space. Test photoelectric sensor in vicinity of Moon. Shell composition: Gold-washed fiberglass. Antenna: Cone itself serves as antenna; gold is conductor. Transmitter: 960.05 mc. at 180 mw. with 3 subcarriers. Power supply: Mercury batteries. Transmitter lifetime: About 90 hrs.	Probe achieved its primary mission, an Earth-Moon trajectory, yielded excellent radiation data and provided a valuable tracking exercise. It is now orbiting the Sun. While the probe reached the vicinity of the Moon, it did not come close enough (20,000 miles) to trigger photoelectric sensor or sample Moon's radiation. The probe passed within 37,300 miles of Moon at 5:24 p.m. on Mar. 4, 1959. It passed 7.2° east and 5.7° south of Moon at 4,490 m.p.h. Probe reached perihelion, 91,700,000 miles, at 9 p.m. Mar. 17, 1959: scheduled to reach aphelion, 106,100,000 miles on Oct. 1, 1959. Injection velocity of 24,790 m.p.h. was 188 m.p.h. below planned velocity. Pioneer IV was tracked for 82 hrs. to distance of 407,000 miles.	--------	--------

See footnotes at end of table.

1. United States and Russian satellites, lunar probes and space probes, 1957, 1958, and 1959—Continued

(Official statistics prepared by the National Aeronautics and Space Administration [1])

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Perigee[2] (miles)	Apogee[2] (miles)
Discoverer I, United States: Satellite (cylinder). Total weight of satellite, 1,300 lb., including 245 lbs. of instruments. Launched from Pacific Missile Range into polar orbit.	Feb. 28–Mar. 5, 1959.	Thor-Hustler Standard Thor booster with a 2d stage designed to go into orbit. Both liquid fueled. Weight, about 108,400 lbs. Height, 78.6 ft.	Dimensions: Length 19.2 ft., diameter 5 ft. Objectives: Check out propulsion, guidance, staging, communications. Antennas: 1 directional and 1 whip antenna. Transmitters: classified but included telemetry and tracking beacon. Power supply: Nickel-cadmium batteries.	Period: 95.9 min. Difficulty in stabilization caused tumbling which hampered consistent tracking acquisition. After about 5 days, it is presumed from tracking reports the satellite burned up on reentry into atmosphere at an unknown point. Inclination: 3° off north-south axis of Earth.	99	605
Discoverer II, United States: Satellite (cylinder). Total weight, 1,610 lbs., including 245 lbs. of communications and performance instrumentation and a 195-lb. capsule. Launched from Pacific Missile Range into polar orbit.	Apr. 13–Apr. 26, 1959.	Thor-Hustler (same as Discoverer I).	Dimensions: 2d stage same as Discoverer I but with a 195-lb. recovery hemisphere-shaped capsule measuring 33 in. in diameter by 27 in. deep. Capsule used small retro rocket to aid reentry. Experiments: To recover capsule; maintain temperature and oxygen sufficient to sustain life; emulsion packs to measure radiation. Antennas: 1 directional and 1 whip antenna. Transmitters: Classified but included telemetry and tracking beacon plus a tracking beacon in recovery capsule. Power supply: Nickel-cadmium batteries. Transmitter lifetime: Telemetry ran to Apr. 14 as planned; tracking beacon ran until Apr. 21 as planned. Capsule composition: Classified.	Period: 90.5 minutes. All equipment worked as programed except timer which ejected capsule. Timer difficulty made capsule impact in vicinity of Spitzbergen Islands Apr. 14 instead of Hawaii vicinity where it was to be recovered either by airplane or ship. Capsule, which contained radiation emulsion packs, has not been found. Temperature-oxygen instruments showed life could be supported. Inclination: 0.2° off north-south axis of Earth.	142	220
Vanguard, United States: 2 satellites. Total weight of scientific payloads, 23.3 lbs.	Apr. 13, 1959–0..	Vanguard SLV 5 (same as TV 3).	Dimensions: Vanguard 3A—13-in. ball with a 17½ by 2½-in. cylinder extending from it. Vanguard 3B—a 30-in. inflatable sphere containing no instrumentation to be tracked optically. Experiments: Vanguard 3A contained a precise magnetometer to be used to map Earth's magnetic field. Vanguard 3B was to measure drag in space. Composition: 3A was made of fiberglass and phenolic resins. 3B was laminated aluminum foil and plastic sheet. Transmitters: For 3A—108 mc. at 10 mw. for tracking and 108.03 mc. at 80 mw. for telemetry on ground command. Power supply: Silver-zinc batteries. Antennas: 4 spring-lock rods.	2d stage failed to operate properly which caused a tumbling motion. Payload and 3d stage fell into Atlantic Ocean several hundred miles off Cape Canaveral. Total flight time, about 500 sec.	0	0
Discoverer III, United States (ARPA): Satellite and nose cone reentry capsule. Scientific payload and total	June 3, 1959–0...	Thor-Hustler stages (2): 1st, Standard Thor modified to accommodate Dis-	Dimensions: Recovery capsule is 27 in. long, 33 in. in diameter, containing environmental equipment; 2d stage, all of which goes into orbit, is same as Discoverer I. Experiments: Measure-	Telemetry indicated 2d stage fired. Tracking stations did not receive telemetry from satellite; doubtful it achieved orbit.	0	0

weight in orbit, 1,600 lbs. (entire 2d stage goes into orbit) including 440-lbs. payload, 245 lbs. of which include communications, telemetry, and performance-measuring instrumentation, plus 195-lb. reentry capsule containing 4 black mice. Launched from Pacific Missile Range into polar orbit.		coverer III; 2d, Lockheed (designed to go into orbit). Gross takeoff weight, 8,400 lbs.; height, 75.9 ft.; diameter (base), 5 ft.	ment of cosmic radiation, biomedical environmental research, and capsule recovery techniques by C-119 aircraft patroling recovery area. Antennas: 1 directional and 1 whip antenna. Transmitters: Classified. Power supply: Nickel cadmium batteries.			
Vanguard (SLV-6): Satellite (sphere). Total weight in flight and scientific instrumentations, 22.5 lbs.	June 22, 1959-0..	Standard Vanguard SLV.	Dimensions: 20 in. in diameter. Experiments: Measurements of solar-earth heating process which generates weather. Shell composition: Magnesium alloy. Antennas: 4 metal rods. Transmitters: (*a*) 108 mc. at 10 mw.; (*b*) 108.03 mc. at 100 mw. Power supply: Mercury batteries.	A faulty 2d stage pressure valve caused failure. A regulator designed to control helium flow, which drives 2d stage propellants into engine, did not respond to command. Pressure then built up within helium reservoir which ruptured about 40 sec. after 2d stage ignition. Without sufficient pressure on the propellants, 2d stage engine ran roughly. Helium tank burst when vehicle was at 40 to 50 miles altitude. The rocket rolled over in a ballistic trajectory at an altitude of about 90 miles. 3d stage ignited before plunging into Atlantic Ocean some 300 miles northeast of Atlantic Missile Range.	0	0
Discoverer IV, United States, (ARPA): Satellite and nose cone reentry capsule. Scientific payload and total weight in orbit, 1,700 lbs. (entire 2d stage goes into orbit) including 300-lb. reentry capsule.	June 25, 1959-0..	Same as Discoverer III.	Capsule contained telemetry equipment to measure its performance.	Failed to achieve orbit. Telemetry reports indicate that 2d stage fired. Satellite was not acquired by tracking stations on its 1st or subsequent orbits. Insufficient velocity caused failure.	0	0
Explorer, United States: Satellite (2 truncated cones joined at bases). Total weight in flight and scientific payload, 91.5 lbs.	July 16, 1959-0..	Juno II (Am-16). Same as Pioneer III.	Dimensions: 28 in. high, 30 in. diameter. Experiments: Measurements of (1) earth's radiation balance, (2) Lyman-alpha X-rays, (3) heavy primary cosmic rays, (4) micrometeorites, (5) cosmic rays, (6) satellite temperature, and (7) erosion study of exposed solar (silicon) cell on outside of satellite. Transmitters: (*a*) 20 mc. at 650 mw.; (*b*) 108 mc. at 15 mw.; power supply: (*a*) solar energy, (*b*) chemical batteries. Transmitter lifetime: (*a*) Cutoff after 1 year; (*b*) 2 months.	Vehicle was destroyed by range safety officer after 5½ sec. when it tilted sharply due to failure of power supply to guidance system.	0	0

See footnotes at end of table.

1. United States and Russian satellites, lunar probes and space probes, 1957, 1958, and 1959—Continued

(Official statistics prepared by the National Aeronautics and Space Administration [1])

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Perigee[2] (miles)	Apogee[2] (miles)
Explorer VI, United States: Satellite (paddlewheel; spheroid shaped with flattened bottom plus 4 solar vanes or paddles). Scientific payload and total weight in orbit, 142 lbs.	Aug. 7, 1959.—Over 1 year.	Thor-Able III stages: 1st, Thor (liquid) minus guidance; 2d, Modified Vanguard 2d step (liquid); 3d, X-248 solid rocket made for Vanguard program. Gross takeoff weight, 105,000 lbs. plus; height, 90 ft.	Dimensions: 26 in. in diameter and 29 in. deep with 4 solar vanes 18 by 18 in. square. Experiments: (1) Measurement of 3 specific radiation levels of Earth radiation belt; (2) TV-like scanning device to relay cloud cover picture; (3) solar cells (8,000 in all; 1,000 on each side of 4 paddles) to create voltage to recharge the satellite's chemical batteries in flight (electronic gear in satellite includes 3 transmitters and 2 receivers); (4) micrometeorite detector; (5) 2 types of magnetometer to map Earth's magnetic field; (6) 4 experiments to study behavior of radio waves, all aimed at learning more about deep space communications. Antennas: 2 dipole aluminum rods. Transmitters: (*a*) 108.06 mc. at 500 mw.; (*b*) 108.09 mc. at 500 mw.; (*c*) ultrahigh frequency (undisclosed). Power supply: Nickel-cadmium batteries rechargeable by 8,000 solar cells mounted on 20 by 22 in. vanes jutting from satellite's equator.	Experiment successful. Data being analyzed as of Aug. 16, 1959. Details will be published when available. Period, 12½ hr.; speed (perigee), 23,031 m.p.h.; speed (apogee), 3,126 m.p.h. Inclination to equator, 46.9°.	156	26,357
Discoverer V, United States (ARPA): Satellite and nose cone reentry capsule. Total weight, approximately 1,700 lb. (entire 2d stage) including 300-lb. reentry capsule. Launched from Pacific Missile Range into polar orbit.	Aug. 13, 1959.—In orbit until Sept. 16, 1959.	Thor-Agena stages (2): 1st, standard Thor; 2d, Agena.	Same as Discoverer IV	Satellite went into orbit, all equipment working as programed. However, reentry capsule was not recovered due to malfunction following its ejection from satellite. Period, 94 min.	136	450
Beacon, United States: Satellite (sphere). Scientific instrumentation in 3d-stage rocket casing 25.8 lb., including 10-lb. inflatable sphere which is ejected to fly into orbit free of payload case. Total weight in orbit including spent 3d stage, 84 lbs.	Aug. 14, 1959–0.	Modified Juno II (AM-19B) stages (3): 1st, Jupiter (liquid); 2d, 11 clustered Sergeants (solid); 3d, 3 clustered Sergeants (solid). Gross takeoff weight, 121,000 lbs.	Dimensions: 7 by 31½ in. (inflatable sphere is 12 ft. in diameter when inflated). Experiments: Inflatable satellite of Mylar plastic film and aluminum foil. Satellite itself contains no instrumentation. Ejection and inflation mechanism consists of nitrogen bottle, a bellows, a piston, and a connecting valve. Shell composition: Stainless steel. Transmitter: 108.03 mc. at 50 mw. (in rocket casing). Power supply: 12 mercury batteries.	Payload failed to achieve orbit due to premature fuel depletion in booster and malfunction in attitude control system for upper stages. Time to 3d-stage burnout (normally time of injection into orbit), 11.07 min.	0	0
Discoverer VI, United States (ARPA): Satellite and nose cone reentry capsule. Total weight, approximately 1,700 lbs. (entire 2d stage) including 300-lb reentry capsule.	Aug. 19, 1959–Oct. 20, 1959.	Same as Discoverer V	Same as Discoverer IV	Same as Discoverer V	139	537

"Lunik II," Russia: Lunar probe (hermetically sealed sphere). Estimate of total payload weight: 858.4 lbs.[7]	Launched 6 a.m. e.d.t. (estimated) on Sept. 12, 1959. Time of impact on the Moon: 5:02:24 p.m. e.d.t. on Sept. 13, 1959.	Multistage rocket. Weight of 2d stage minus fuel: 3,324 lbs. Other details: undisclosed.	Dimensions: not given. Experiments: Instruments to measure temperature and pressure inside vehicle; instruments to study magnetic fields of Earth and Moon; meteoric particles in space; heavy nuclei in primary cosmic radiation and other properties of cosmic rays. Shell composition: Pentagonal strips of stainless steel made of two hermetically sealed shells of aluminum-magnesium alloy. Antennas: Not disclosed. Transmitters: (a) 183.6 mc. (altimeter in probe); (b) 39.986 mc. (in probe); (c) 19.993 mc. (in probe); (d) 20.003 mc. (in rocket); (e) 19.997 mc. (in rocket).	58.4-lb. lunar probe hit surface of the Moon at 5:02:24 p.m. e.d.t. 1 minute and 24 seconds later than predicted by Russia scientists; total flight time: about 35 h. (The probe contained scientific instruments and the Soviet coat of arms.) When it hit the Moon, the container was traveling more than 2 miles per second. (Expended final stage also hit the moon.)	Distance traveled, 236,875 miles	
Transit I. United States (ARPA): Satellite (sphere). Total weight in flight and scientific payload: 265 lbs.	Sept. 17, 1959–0	Standard 3-stage Thor-Able.	Dimensions: 36 in. in diameter. Shell composition: 2 layers fiber glass with honeycomb structure in between. Antennas: Broad band spiral antenna painted on outside of shell. Transmitters: (a) 54 mc.; (b) 162 mc.; (c) 216 mc.; all at 100 mw. Power supply: 2 silver zinc; 2 nickel-cadmium; latter 2 powered by solar cells.	Satellite failed to achieve orbit. The 2d stage fired on schedule but the 3d stage did not fire.	0	0
Vanguard III (SLV-7), United States: Satellite (sphere from which tapered tube extends); scientific payload of 50 lbs. and attached 3d-stage together weigh about 100 lbs.	Sept. 18, 1959—estimated 30 to 40 years.	Vanguard satellite launching vehicle 7. Stages: 3; 1st: liquid (GE); 2d: liquid (Aerojet); 3d: solid (ABL). Gross takeoff weight: approximately 22,600 lbs. Height: 72 ft. Diameter (base): 45 in.	Dimensions: 20-inch sphere from which a 26-inch tapered tube extends. Experiments: Measurements of earth's magnetic field, solar X-rays, and environmental conditions in space. Shell composition: Highly polished silicon-monoxide-coated magnesium. Antennas: 4 metal rods. Transmitters: (a) 108 mc. at 30 mw., tracking and X-ray and environmental; (b) 108.03 mc. at 80 mw. for magnetometer and command. Power supply: Chemical batteries. Transmitter lifetime: Programed for about 90 days.	To be announced at a later date	319	2,329
Lunik III, Russia translunar earth satellite ("automatic interplanetary station"). Total payload weight in orbit: 614-pound scientific satellite. Last-stage rocket, weighing 3,423 pounds without fuel, also went into orbit. It contained 345 pounds of scientific equipment.[7]	Oct. 4, 1959, at 5 a.m. Moscow time (Oct. 3, 1959, at 10 p.m. EDT, New York time). Very long lifetime expected.	Not disclosed	Dimensions: Not disclosed. Experiments: Two cameras, developing mechanism and automatic devices for triggering cameras, developing processes and transmission of pictures to earth. Also automatic temperature control mechanism. Other experiments not disclosed. Shell composition: not disclosed. Antennas: 4 metal rods. Transmitters: (a) 183.6 mc. at (estimated: between 5 and 20 watts); (b) 39.986 mc. at (not disclosed). Power supply: Solar cells and chemical batteries.	Rocket left earth at 25,000 mph. The payload separated from the last stage and reached closest point to moon—4,373 miles—on Oct. 6. When satellite was about 40,000 miles from moon's surface, the cameras were triggered. They produced photographs of high precision showing 70 percent of moon's backside. Cameras were operated on Oct. 7, 1959, for 40 minutes. Pictures were transmitted to earth shortly before reaching perigee on Oct. 18, 1959.	Lunik III reached its apogee 292,000 miles from surface of the earth on Oct. 10; it reached 1st perigee, 24,840 miles from surface of the earth on Oct. 18, 1959. The 625,000-mile, 15-day, elliptical orbit is highly eccentric.	

See footnotes at end of table.

1. United States and Russian satellites, lunar probes and space probes, 1957, 1958, and 1959—Continued

(Official statistics prepared by the National Aeronautics and Space Administration [1])

Name, by type, orbit weight, payload weight	Lifetime	Launching vehicle	Payload instrumentation	Test results	Perigee[2] (miles)	Apogee[2] (miles)
Explorer VII, United States NASA-Army): Satellite (2 truncated cones joined at base). Scientific payload and total weight in orbit: 91.5 lbs.	Oct. 13, 1959 (11:31 a.m. e.d.t.)—20 years.	Modified Juno II (19A).	Dimensions: 30 in. in diameter, 30 in. long. Experiments: Radiation balance; Lyman-alpha X-ray; heavy primary cosmic ray; micrometeorite; cosmic ray; exposed solar cell; temperature measurements. Shell composition: Fiberglass and sand-blasted aluminum foil. Antennas: 20 mc. turnstile antenna consists of 4 flexible quarter wavelength elements which are unreeled in the plane of the satellite equator from a motor-driven drum on the spin axis: 108 mc. turnstile antenna with 4 rod elements. Transmitters: (*a*) 108 mc. at 10 mw.; (*b*) 20 mc. at 600 mw.; (*c*) 40 mc. at 15 mw.; (*d*) 60 mc. at 5 mw. Power supply: Solar cells and rechargeable nickel-cadmium batteries.	Satellite went into predicted orbit, all equipment working as programed. Details of data reduction will be published when available. Period: 101.33 min. Inclination to Equator: 50.3°. Velocity at perigee: 17,285 m.p.h. Velocity at apogee 16,028 m.p.h.	[8] 342	680
Discoverer VII, United States (ARPA). Satellite and nose cone reentry capsule. Total weight, approximately 1,700 lbs. (entire 2d stage) including 300-pound reentry capsule.	Nov. 7, 1959.—Approximate lifetime, 2 weeks.	Same as Discoverer V.	Same as Discoverer IV	Satellite went into orbit, however, reentry capsule was not released due to malfunction of electrical system and possible lack of stabilization.	100	520
Discoverer VIII, United States (ARPA). Same as Discoverer VII.	Nov. 20, 1959.—Approximate lifetime, 2 weeks.	Same as Discoverer V.	do	Satellite went into orbit, however, although reentry capsule was ejected it was not recovered and search was abandoned.	130	1,035
Atlas-Able IV, U.S. lunar probe (paddlewheel; spheroid with 4 solar vanes or paddles). Scientific payload: 372 pounds. Mission: To obtain basic measurements of the lunar environment.	Nov. 26, 1959.—0. 2:26 a.m.	Atlas-Able. Stages: 3. 1st: U.S. Air Force Atlas ICBM modified to accommodate extra stages. 2d: Liquid propellant, adapted from earlier Able rocket vehicles. 3d: Solid propellant modified from earlier Able and Vanguard rocket configurations. Gross liftoff weight: 260,000 pounds plus. Height: 98 feet.	Dimensions: 39 inches in diameter and 55 inches deep with 4 24- by 24-inch square solar vanes jutting from probe's equator. Experiments: (1) Measurements of 3 specific energy levels of cosmic rays; (2) TV-like scanning device to relay lunar surface picture; (3) solar cells (8,800 in all; 1,200 on each side of 4 solar vanes to create voltage to recharge the probe's chemical batteries in flight (Note: Electronic gear in probe includes 2 transmitters and 2 receivers); (4) micrometeorite detector; (5) 2 types of magnetometer; (6) radio wave experiments. Antennas: 4 dipole aluminum rods. Transmitters: 2 ultrahigh frequency 378 mc. transmitters at 5 watts. Power supply: Nickel cadmium batteries rechargeable by solar cells (see above). The payload also contained a small engine to provide in-	Countdown was normal and liftoff went as scheduled. 46 seconds after liftoff, 2d stage guidance transponder no longer responded to interrogation. At 104 seconds, 2d stage telemetry was lost. Atlas booster and sustainer operated as scheduled but about 45 seconds after launch the plastic shroud covering the lunar probe fell off. As the shroud fell away, the vehicle was approaching maximum atmospheric pressure loads. With the shroud gone, the payload was torn off. Radar indicated that the 2d	(Altitude unknown.)	

		Diameter at base: 16 feet.	flight velocity corrections. The probe payload had 2 thrust chambers, 1 to step up velocity, the other to supply reverse thrust when probe approached moon's gravitational field. Each chamber could deliver 20 pounds of thrust.	stage ignited but there was no indication that it separated. Reason for the shroud dropoff and mission failure is under study.

[1] Except where indicated, this chart does not include description and weights of spent rocket casings, etc., that have gone into orbit or flight trajections along with payloads.
[2] All distances are given in statute miles above the surface of the earth.
[3] Altitude: 40,000 to 70,000 ft.
[4] Altitude: About 70,700 statute miles.
[5] Altitude: 963 miles.
[6] Altitude: 63,580 miles.
[7] These are unofficial figures culled from U.S. press, Pravda, Moscow radio, etc.
[8] Oct. 27, 1959.

NOTE.—All statistics listed above, with exception of the Russian figures, are official. Statistics from here on are subject to updating when study of data has been completed. All Discoverer satellites are sponsored by the Advanced Research Projects Agency of the Department of Defense and are launched by the Air Force. All statistics on Discoverer experiments have been supplied by ARPA.